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Twentieth Century Problems
A Retrospective Mini-Assessment

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NINETEENTH CENTURY TECHNOLOGY - TWENTIETH CENTURY PROBLEMS

A RETROSPECTIVE MINI-ASSESSMENT

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The systematic attempt to anticipate future environmental problems has usually been associated with the assessment of new or emerging technologies. In recent years, however, it has become clear that environmental problems may suddenly come to light, stemming from aging or obsolescent technological systems, or from industrial practices that have already been discounted or superceded by improved methods.

This retrospective mini-assessment of nineteenth century technology has identified industrial and urban technologies of the pre-World War I era which may be the sources of present-day environmental problems or threats to public health and safety. Four case studies were given particular attention in the assessment: (1) arsenic, which was used widely in a number of industries during the last century; (2) coal, which is being reintroduced as a major energy source; (3) iron and steel, the major heavy industries of the nineteenth century; (4) old dams, which potentially contain hazardous materials in the trapped sediments.

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NINETEENTH CENTURY TECHNOLOGY - TWENTIETH CENTURY PROBLEMS

ABSTRACT

This Retrospective Mini-Assessment of nineteenth century technology identified industrial and urban technologies of the pre-World War I era which may be sources of present-day environmental problems or threats to public health and safety. Using interdisciplinary analysis, bibliographic review, and expert consultants, the research team developed criteria for defining long-enduring hazards. Twenty-four technologies, systems, or industrial materials were identified as potentially significant problems.

The most serious generic problem stemming from nineteenth century technology is residual toxic substances. They are known or likely to be found in soil and groundwater, concentrated in land waste dumps and in lake and reservoir sediments, embedded in old buildings and reclaimed building materials, or as components of antique furnishings and artifacts. Detailed case studies were made of four topics: the coal industry, the iron and steel industry, the widespread industrial use of arsenic compounds, and toxic-laden sediments behind old dams.

Abandoned industrial or mining sites may now be a source of significant but unrecognized health problems in many localities. Land reclamation, dredging, facility rehabilitation, or restoration of antiques may entail particular hazards for special groups, such as construction workers, remodelers, museum curators, and hobbyists. It is recommended that EPA and other agencies conduct further investigation of such hidden environmental time bombs, and that EPA develop information, technical assistance, and assessment guidelines for use by local governments, State agencies, trade unions, special interest groups, and the public to help in identifying site-specific or activity-specific hazards left over from the past.

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NOTICE

Mention of trade names or commercial products does not consititute endorsement or recommendation for use.

1.0 INTRODUCTION AND OVERVIEW

EPA's Strategic Studies Program, in the Office of Strategic Assessments and Special Studies (OSASS), is responsible for identifying future environmental trends or problems that may affect the priorities, responsibilities, and mission of the agency in the foreseeable future.

The systematic attempt to anticipate future environmental problems has usually been associated with the assessment of new or emerging technologies. In recent years, however, it has become clear that environmental problems may suddenly come to light, steming from aging or obsolescent technological systems, or from industrial practices that have already been discontinued or superceded by improved methods. Examples of such problems are subsidence or acid drainage from abandoned mines, deteriorating urban sewer systems, unsafe bridges, leaking waste depositories, and eroded earthen dams.

A wave of critical and unforeseen environmental problems whose source lies in the past, sometimes beyond attribution or liability, and whose costs must therefore often be borne by the public, could drastically affect the priorities, programs, and budget allocation plans for EPA over a period of many years.

Cognizant of these problems, OSASS has solicited proposals for small assessment studies in the area of "retrospective forecasting" to explore the value of historical research as a technique for identifying potential environmental problems.

1.1 THE NINETEENTH CENTURY

The nineteenth-century was the period when burgeoning technology and industry transformed America from an agrarian, developing country to an industrial, urbanized nation. In 1800, only 6 percent of the U.S. population lived in urban areas; by 1900, that figure had grown to 40 percent, and two decades later the 50-percent mark had been passed.[1]

The Industrial Revolution was transforming Europe at the same time. But even in 1800 Britain and France were major world powers. Britain in particular was the center of industrial know-how and risk capital, and dominated the seas. The United States in 1800 was a peripheral nation recently emerged from colonialism; its political unity was still somewhat precarious, but it had enormous undeveloped territories and resources.

It is the second half of the nineteenth-century, however, which is the focus of this study. Following the turmoil of the Civil War (1861-1865), which was won by the North partially because it was more industrialized, the wartime industries were able to turn to extending railroad systems and increased production. The nation was at last firmly knit together, not only politically but also economically by markets and by railroad and telegraph lines that spanned the nation from east to west. The Northeast remained politically dominant, and by virtue of steam shipping and transoceanic telegraph cables (both developed in the 1860's and '70's), the area was tied into international markets as well.

Between 1840 and 1850 the urban population of the United States nearly doubled. It continued to grow rapidly throughout the century, fed both from the countryside and, more dramatically, by waves of immigration. Very often, the early immigrants already had industrial training.[2] Labor was available for industrialization; raw materials and capital were available also.

Many of the industries that developed during this period--such as the iron and steel, coal, railroad, and communications industries--are still among the dominant forces in the United States economy today. Others have since declined in importance or have disappeared. Almost all have undergone thorough changes in technology, fuel use, labor categories, scale of enterprise, and--in many cases--geographical areas of concentration.

Industries that have spanned the last 100 years are now subjected to environmental, health, and safety regulations that did not exist in their early days. Some of the residues of earlier, unregulated practices, such as dumping wastes on the site or in flowing streams, have never been cleaned up.

Some of the materials that were freely used in consumer products or in construction are now (and in some cases, were even then) known to be hazardous. These materials may exist today in items that are still used or that are collected, displayed, and admired; in buildings that are used or uninhabited; and in those materials in "latent storage" (dust and debris in abandoned buildings, refuse piles and pits, or built-up sediments at the bottom of bodies of water).

The nineteenth-century also saw the beginnings of the great public works systems that make modern cities possible. For example, in 1802, Philadelphia was the first American city to build a piped water delivery system, followed closely by New York, Boston, Detroit and Cincinnati. By 1860 the 16 largest U.S. cities, and 120 other smaller cities, had piped water. Between 1860 and 1880, 426 additional municipal systems were built.[3]

These systems had the effect of greatly increasing water use; large volumes of water were brought into the cities, with no way to take it out again. Sewer building began in the United States in the 1870's. By 1890 there were 6,005 miles of water carriage combined systems (those that carry sanitary water or sewage, and storm runoff) in cities of over 25,000 people. By 1909 there were nearly 25,000 miles of sewer lines in cities of over 30,000 people, and the number and mileage of systems in smaller communities is unknown.[4]

These and other technologies (including transportation, communication, illumination, waste collection, and construction technologies) permitted greatly intensified urban land use, in part by removing some of the environmental constraints of the earlier nineteenth-century. Once introduced, they tended to be put in place in great numbers of communities within a very short span of time.

Many of the public or urban technologies were constructed as underground systems, and over time utilization of the overlying land became even more intense. For underground systems, deterioration is not highly visible, and maintenance, repair, or replacement is difficult and expensive. This raises the question of whether such systems have "a natural lifetime," and if so, whether they might begin to fail at about the same time (having been put in place concurrently), causing "epidemics" of environmental and health problems across the nation.

As originally planned, this mini-assessment was to provide an exploratory survey of possible environmental problems that might arise in the future from nineteenth-century "public works" or "urban technologies." For reasons discussed in Section 4.2, it was decided at an early phase of research to direct our exploration toward nineteenth-century industrial processes instead.

1.2 TOXIC SUBSTANCES

Toxic substances in the environment are a major public concern at present, especially following the discovery of contamination around Love Canal. This episode was a result of leaking industrial wastes that were stored in the 1930's and 1940's in Love Canal (Niagara Falls, N.Y.), a canal that was built in the nineteenth-century and later abandoned and filled in. This episode involved twentieth-century wastes, but toxic materials were widely used in nineteenth-century manufacturing also. Many of these toxic materials do not degrade; their toxicity endures, and neither their original location, in many cases, nor their present location is known. They may have been transported by erosion or stream currents; they may have leached into underground water supplies; or they may have been moved by dredging or excavation.

The residual contaminants from the last century are undoubtedly dwarfed by the detrimental byproducts of the chemical revolution in American industry during and after the Second World War. But in some local areas, they may well be a serious--and unrecognized--problem. There are recurring episodes of the discovery of old waste dumps and resulting public alarms; some examples are mentioned in this report. The older contaminants--those which are inorganic--may in general be more persistent than modern synthetic organic chemicals.

As we have already pointed out, such hazardous materials as arsenic, lead, and mercury were used in many consumer products in the past; these items are now "antiques" to be collected, refurbished, and displayed or used. Victorian houses and furnishings are much sought after for restoration. If some of the materials or components of these items entail even low-level risks of chronic or acute toxicity, either during their rehabilitation and restoration or to the eventual users, warnings to the public or instructions as to careful handling may be needed.

Such problems could become even more important in the future. As a result of rising energy costs and increased emphasis on energy conservation, there is now a movement toward re-urbanization and reclamation of land and buildings in cities, especially in the Northeast. Recycling of products and materials, and recovery of energy from refuse is also increasing. Old, small-scale dams are being retrofitted and small-scale hydropower plants, retired in the middle of the twentieth-century, are being rehabilitated. The goal of re-industrialization to improve capital plants may involve either modernization, or demolition and replacement of old industrial facilities.

Re-industrialization, re-urbanization, reclamation, restoration, rehabilitation, and recycling--the 6 R's, as we call them in this report--could well cause some environmental "costs" of the last century to re-emerge as continuing risks or disposal problems to plague this century. An initial effort to explore and assess this possibility was the objective of this mini-assessment.

1.3 A NOTE ON THE MINI-ASSESSMENT

It should be noted that we have been very loose in our use of the term "nineteenth-century." Most of the concerns that were identified began in the latter half (and especially the final third) of the 1800's. The technology and/or practices that caused such concerns were in many cases in use until the 1920's and in some cases a decade or two longer. To have bounded this exploratory survey rigidly by dates, therefore, would have been uselessly pedantic.

The exploratory nature of this study should be emphasized. It was aimed at problem definition and at assessing the possible need for further research in this area. The methods used were a survey of secondary historical literature on technology and manufacturing, and extensive interviews with historians, museum curators, and "others"--any individuals we could locate who by occupation or personal interest were informed about the technology of the past. In most cases, it was necessary to spend considerable time explaining our topic, since few of these people had ever thought in terms of present risks from past technology. This is a largely unexplored subject, even though there are known episodes of such risks coming to light.

We are particularly indebted to our consultants, who suggested sources, participated in a 1-day staff workshop, reviewed drafts, and generally shared their knowledge with us: Professor Joel Tarr of Carnegie Mellon University, Professor Clay McShane of Northeastern University, Dr. Brook Hindle of the Smithsonian Institution's Museum of Technology and History, and Dr. Philip Ritterbush of the Institute for Cultural Change. Others who generously helped us through interviews and telephone inquiries are listed in Appendix II.

1.0 FOOTNOTES

[1] U.S. Bureau of Census, Historical Abstracts

[2] Porter, J., Merchants and Manufacturers, (Baltimore: Johns Hopkins Press, 1971).

[3] Tarr, Joel, "Retrospective Assessment of Wastewater Technology in the United States," Carneigie Mellon University, 1978 (in publication).

[4] Ibid.

2.0 NINETEENTH CENTURY INDUSTRY

The rapid growth and dissemination of technology in America from 1860-1900 is striking, even after the first century of the Industrial Revolution. Investment capital was freed by the end of the Civil War. The success of the railroad, the telegraph, and steam shipping were excellent examples of the rewards of entrepreneurial daring. Advances in transportation, communication, illumination, and energy generation encouraged and supported other industrial innovations, as did changes in merchandising, financing, and management practices. The social costs of industrial progress were becoming ever more clear (Karl Marx was writing Das Kapital in 1860), but as yet there were few statutory or regulatory barriers to contend with, and profits were almost untaxed.

The 1860 Census of Manufactures listed 27 industries in the United States:

Cotton goods
Woolen goods
Worsted goods
Hosiery
Wool carding, cloth fullering
Carpetings
Clothing
Boots, shoes
Women's clothing
Straw goods
Silk manufacturing
Linen manufacturing
Hemp and manila cordage
Printing
Bookbinding, blank books
Musical instruments
Coal mining
Iron mining
Iron, iron manufacture
Machinery, steam engines, etc.
Steel
Salt manufacture
Agricultural instruments
Hemp bagging
Paper
Hats and caps

It should be noted that most of these industries (about 19 of the 27) dealt with organic materials, chiefly common agricultural products, although some inorganic chemicals would have been used. (As a general rule, inorganic compounds in commerce are more likely to be both toxic and persistent than are organic compounds.)

The next census, in 1870, listed an additional 15 industries, still heavily weighted toward processing of agricultural products:

Flax and jute bagging
Cheese, dairy products
Leather, curried and tanned
Brick and tile
Lead, pig
Nails, tacks

Sugar and molasses, raw and refined
Tobacco
Cutting of peat
Lumber, sawed
Elastic goods
Sewing machines
Quarrying: stone, slate, marble
Boring for mineral oil
Tar and turpentine

By 1880, the number of industries listed had risen sharply, to 332. A large number of these involved minerals processing, chemicals, and more sophisticated manufacture. A partial listing of these industries includes:

Zinc
Vulcanized rubber
Starch
Sheet iron ware
Mucilage, paste
Lead pencils
High explosives
Kaolin, ground earths
Sheet metal
Coke
Dyestuffs, extracts
Felt goods
Ammunition
Brassware
Celluloid
Varnish
Smelting, refining
Tinware
Looking glass
Paints
Galvanizing
Artificial ice
Lead bar
Shot
Drugs, chemicals
Electroplating
Fertilizers
Blacking
Bluing
Veneers
Soda water
Copper ware
Matches
Patent medicines
Graphite
Japanning
Pipe
Coal tar
Dyeing, cleaning
Enameled goods
Enameling
Babbitt metal, solder
Bronze castings

Nearly all of the 1880's industries listed above could involve environmental problems.

By 1900, the Census showed that industry had greatly increased in diversity and scale. Most businesses were of course small, with fewer than 10 workers on the average and low capitalization (see Table 2-1). The heavily capitalized industries--iron and steel, illuminating gas, cotton and wool manufacture, railroad shops--tended to be both more concentrated and larger in scale (see Table 2-2). Both dispersion and scale are important in assessing the significance of associated risks.

There were hazards and environmental problems associated with the small-scale industries as well as the large. For example, there were 12,466 establishments in 1900 doing tin, copper, and lead plating. Such materials as mercury, arsenic, lead, cyanides, and sulfuric acid would have been used in these businesses. There were about 76 million people in the United States in 1900, of whom 30 million lived in urban areas; this means there was a plating shop for every 2,400 city dwellers. Pollutants from small industries were no doubt widely dispersed through all American communities, small as well as large.

Public health and safety hazards associated with some toxic substances were well known in the nineteenth-century. Arsenic, for example, has been considered a deadly poison throughout history. In the Middle Ages it was remarked that scribes who illuminated precious texts with metallic paints were subject to certain illnesses, and the connection was made to their habit of moistening their paint brushes with their tongues while using lead and mercury.[7] Paracelsus, around 1530, had warned of

TABLE 2-1

Industries by Number of Establishments, 1900

Rank industry	(millions) Capital	Capital per establishment	Number of workers	Number of establishments	Workers per establishment
(1) Blacksmiths, wheelwrt.	55.0(36)*	1,000	36,193(36)	51,771	0.7
(2) Lumber, timber trade	611.4(2)	18,000	283,179(3)	33,010	8.6
(3) Men's clothing	173.0(13)	6,000	191,043(5)	28,014	6.9
(4) Flouring, grist mills	218.7(9)	3,000	37,073(34)	25,258	1.5
(5) Printing, publishing	292.5(8)	13,000	162,992(7)	22,312	7.3
(6) Carpentering	71.3(31)	3,000	123,985(10)	21,315	5.8
(7) Paint, paper hanging	27.2(55)	1,000	59,191(22)	16,939	3.5
(8) Milliners, custom	27.7(54)	2,000	33,298(38)	16,151	2.1
(9) Bread, baking	81.0(28)	5,000	60,271(21)	14,917	4.0
(10) Tobacco, cigars	67.7(32)	4,000	103,462(11)	14,539	7.1
(11) Saddles, harnesses	43.3(42)	3,000	24,123(40)	12,934	1.9
(12) Tin, copper, lead plate	55.7(35)	4,000	45,375(30)	12,466	3.6
(13) Plumbing, gas and steam	47.1(40)	4,000	53,916(24)	11,876	4.5

---

*( ) = rank

SOURCE: 1900 Census of Manufactures.

TABLE 2-2

Industries by Capitalization (1900)

Rank	industry	(millions) Capital	Capital per establishment	Number of workers	Number of establishments	Workers per establishment
(1)	Foundries, machine shops	$665.0	7,000	350,327(15)*	9,321(15)*	37.6
(2)	Lumber, timber trade	611.1	18,000	283,179(3)	33,010(2)	8.5
(3)	Iron, steel	573.4	858,000	222,490(4)	668(41)	333.
(4)	Gas, illuminating and heating	567.0	646,000	22,459(47)	877(36)	25.6
(5)	Cotton manufacture	467.2	443,000	302,861(2)	1,055(33)	287.
(6)	Cars, steam railroad	415.3	275,000	39,532(33)	1,509(27)	26.1
(7)	Woolen manufacture	310.2	219,000	159,108(8)	1,414(28)	112.5
(8)	Printing and publishing	292.5	13,000	162,922(7)	22,312(5)	7.3
(9)	Flouring, grist mills	218.7	9,000	37,073(34)	25,258(4)	1.5
(10)	Slaughterhouses, etc.	190.7	169,000	69,441(17)	1,131(31)	61.4

---

*( ) = rank

SOURCE: Census of Manufactures.

the danger of mercury poisoning in mining and metallurgy, and in France at this time, workers in the mercury distillation trade were allowed only one month's employment per year. In 1556 Georgius Agricola wrote a classic book on all aspects of metallurgy (De Re Metallica), which includes a section describing diseases and accidents among miners. In 1700, Bernardino Ramazzini, who "is to occupational medicine what Galileo and Newton are to physical science," described occupational diseases associated with pyrite roasting, dyeing, mercury smelting, silvering of mirrors, and glassblowing.

During the 1700's there were other landmarks: lead poisoning was identified among workers who lined cider vats with lead; scrotal cancer among chimney sweeps (from the effects of coal soot) was recognized; and Charles Thrackrah and Thomas Beddoes identified and studied a number of other occupational diseases. But as Irving Sax notes in his exhaustive book, Dangerous Properties of Industrial Materials:

> The nineteenth-century was a turning point for occupational medicine. The advent of the industrial society and the absence of social legislation make this the low point in society's concern for the worker and his health. The excesses of dangerous occupations and hazardous employment brought about a new social consciousness in Western society.... (and) a reform movement was generated which has lasted well into the twentieth century.[2]

It was, however, the "low point" that prevailed during most of the years considered in this survey. The occupational safety and health reform movement did not really bear fruit until well into the twentieth-century. In 1898 the U.S. Supreme Court recognized for the first time that the health of the laborer was "a public benefit" to be protected. Between 1905 and 1909 about 21 states enacted some legislation to regulate industrial working conditions.

Legislation to protect consumers came equally late, after the "muckrakers" had revealed horrifying secrets about industrial processes. The Food and Drug Act of 1906 was the first Federal landmark in this area.

Environmental and public health legislation related to toxic substances did not exist at this time, at least not at the Federal level. The Federal Insecticide Act of 1910 was the first piece of regulatory legislation in the area; it authorized the Department of Agriculture to regulate the sale of fungicides and insecticides by requiring accurate labeling, but did not ban the use of any particular material. The first national water quality legislation was not passed until 1948.

Within the scope of this study it was not possible to investigate state and local laws and regulations. There were local ordinances that dealt with nuisances, but they appear to have imposed few restraints on industrial practices. A society that tolerated extreme exposure to known toxic substances in the workplace was unlikely to be alarmed about more diffuse public health effects or contamination of land, water, and wildlife. In any case, very little was known about such effects, and instrumentation to measure and detect contamination was not developed until much later.

During this period just as today, waste materials were reused in the limited cases when this was economically desirable and technically feasible; otherwise they were discarded. In the early days of an industry or of a specific facility, the solid wastes were usually heaped on some unused part of the property; or--especially when they became too voluminous--they might be used to fill gullies and ravines, they might be carted to some unowned waste land, or, if possible, they might be dumped into the sea or a convenient bog. Liquid wastes ran into the ground or were piped into a running stream, which was regarded as the cleanest means of disposal. (Streams were generally believed to purify themselves in a few yards of flow.) America, after all, was not densely populated, land in most places was cheap, and except along the Eastern seaboard it was still thought of as almost unlimited.

Before passing on to discussion of specific areas of concern, it is worth pausing to note that there are also some positive lessons from the nineteenth-century. Before the "throw away economy," there existed in this country an ethic of frugality and prudence, expressed in the well-known phrase "use it up, wear it out, make it do." The activity now known as recycling was widely practiced, motivated not so much by concern for the environment as out of concern for dollar values. The Twelth Census of Manufactures in 1900[9] included a section on "Utilization of Wastes and By-Products," which noted that:

> The collection of (city) refuse has been made only within a comparatively few years, but is now carried on systematically, being more or less self-supporting and advantageous from an industrial point of view. Formerly this refuse was simply accumulated and disposed of by burning, or casting into streams or onto waste land. Now, bones, glass, rags, iron, paper, and other articles are separately collected and sold.
>
> Old tin cans are used (1) for the recovery of solder, (2) for the recovery of the tin, and (3) for re-melting in the manufacture of steel or iron.[10]

It is clear from the Census report, however, that Europe was further advanced in recycling technology than was the United States. There were several possible reasons for this: the more advanced state of industrialization, especially in Britain, as compared to America; the denser, more compact population and industrial centers in Europe; higher labor costs in America, and the American perception of almost unlimited resources, a carryover from frontier days.

New York City's garbage, according to the Census report, was disposed of by "what is known as the Arnold utilization process, which is...steam digestion and separation of the cooked product into greases and fertilizer fillers." The solids were dried, screened, and sold to manufacturers of "complete fertilizers," which were used particularly in the cotton belt. The greases, however, were "nearly all" shipped abroad where "it is believed" they were refined and separated into "glycerin, red oil, lard oil, and inferior grades." The note of uncertainty was introduced because "the secret of the trade seems to be held abroad," and "it is not known that refineries in this country are as yet able to handle" garbage grease.

Other striking examples of recycling or recovery of energy noted in the Census report include the following:

- Inflammable refuse from industry or cities was often thrown into furnaces making steam for electricity. Glasgow, Scotland, in this way was producing "9,000 horsepower per day or ten hours of power for manufacturing processes."

- Slag from England's iron and steel industry was being used "as a substitute for artificial porphyry in the construction of buildings and for street pavement." Metz, Brussels, and Paris had "paving stones" made of slag, as did Russia. Papers were read before American professional societies proposing methods of using slag for "good bricks" and "cement equal to the best Portland cement," but slag in America was apparently still being used only "to fill up gullies and ravines" and otherwise dumped on land or "thrown into the sea, if such a disposition could be made of it."

- In "economically conducted paper mills" carbonate was recovered from the alkaline liquors in which rags had been boiled, and reused; formerly this water was "allowed to run to waste," i.e., was dumped into streams.

- The "products of the gray brain matter of calves" (products unnamed) were recovered from slaughterhouses and used to treat "affections of the nervous system," such as "neurasthenia, agoraphobia, chorea, and psychosis."

- Reuse of wastes from the leather industry included leather-board from scraps, glue manufacture from scraps and skin, hair used for "cheap blankets and cloth," and recovery of lime salts and degras (grease from washing liquors).

- "Old rubber as a waste material is a thing of the past," being now blended with new rubber after treatment or melted and applied to fabric.

- Mash-ton grain from breweries was used for cattle food mixed with hay, and carbonic acid gas resulting from fermentation was sometimes collected and used for making "soda water."

- Remnants of tin plate and freshwater mussel shells were made into buttons.

- Broken glass was used in France, but apparently not in the United States, to make artificial stone.

The Census mentioned dozens of patents applied for, usually by Europeans, for the recovery and reuse of other waste materials and byproducts, or used consumer products. Some of these were probably later developed and incorporated into industrial processes. However, with the onset of the twentieth-century, the declining cost of energy, the development of petrochemicals, automation, and advances in synthetic materials were to bring about a "once through" economy that discouraged the enthusiasm for recycling and energy recovery--at least until the advances of science and instrumentation had revealed the environmental and health costs of indiscriminate waste disposal. In 1900, petroleum was just beginning to displace coal. Eighty years later, the realization that petroleum resources could be used up within a few generations is reawakening interest in recycling and energy recovery.

2.0 FOOTNOTES

[1] Irving Sax, Dangerous Properties of Industrial Materials, ch. 1, pp 1-6.

[2] *Ibid*.

[3] U.S. Department of Commerce, Twelth Census of Manufactures, 1900.

3.0 CRITERIA FOR SELECTION OF TOPIC AREAS

This mini-assessment was developed to probe the likelihood that as yet unidentified environmental problems may derive and arise from events far in the past. At the beginning of the study, staff members and consultants generated long lists of possible topics for investigation. Our only criterion at this point was that the topics be related to nineteenth-century industry and that they have a potential for environmental effects that could feasibly have survived or endured for many decades.

We attacked this problem from two viewpoints: we looked at prominent nineteenth-century industries to find potential hazards, and we reviewed twentieth-century concerns (especially the List of Toxic Substances) and considered their historical antecedents. In both exercises we consulted numerous historians. Nevertheless, our lists were not exhaustive, and we have perhaps only scratched the surface in this exploration.

Our lists included industries, technological systems or clusters of systems, raw materials and other inputs, and products or byproducts. Although several attempts were made to simplify and systematize these lists--that is, to cut out overlapping between categories or to reduce all of the topics to technologies or to materials--it appeared more useful in the long run to leave the list of candidates eclectic.

After initial work-ups of some salient historical data and simple characterizations of the topics and associated environmental concerns, there was a 1-day workshop for staff, consultants, and EPA program managers. The participants both added to and refined the list; they also discussed sources of information, and most importantly, developed a set of criteria for selecting and narrowing study topics. These criteria, which were further defined after consultation with EPA/OSASS program managers, are discussed below. Note that they require some readjustment according to whether they are being applied to materials, technologies, industries, or products.

The first three criteria were of course the most important, but the other factors were considered, both in refining the list of candidate topics and in selecting four among them for somewhat more detailed case histories. Section 4 discusses the application of these criteria.

CRITERIA

1.0 ENVIRONMENTAL FACTORS

1.1 Risk

Does the subject involve the possibility of risk to health and safety, or environmental damage? This is of course the question to be investigated through further assessment. But many candidates that appeared on early lists were discarded because there was no sound rationale for suspecting detrimental impacts.

1.2 Persistence

Could the source of risk have survived the passage of time? Could it be generating detrimental impacts today? Or could it be capable of generating them in the future, if the source were brought out of storage, either deliberately by restoration or inadvertently by excavation or dredging? We are concerned only with present and future risk or problems, not historical ones.

1.3 Dispersion and Scale

If a risk or problem exists, would it be of importance? A subject was considered to meet this criterion if the problem could be either:

- Widespread, affecting many people or large parts of the country;
- Highly concentrated in one or more regions or localities in which it might present severe problems;
- Capable of exposing categories of people, segments of the population, or special environments to special risks.

1.4 Portability, Transport

Could the problem have expanded over time? Could surviving sources of risk spread? Could they have been relocated? For example, toxic substances can be transported by natural forces--leaching, erosion, or water currents; contaminated soil might be reused elsewhere as landfill. This would make any hazard doubly unsuspected and hard to identify.

1.5 Historical Unawareness

Was the risk or problem recognized in the nineteenth-century? The toxicity of some materials has been recognized only recently due to advances in medical science and biological science and in measurement capabilities, or because the detrimental impacts are very slow to mature or cumulative. The hypothesis was that materials whose risk was well recognized would have been handled more carefully. However, research indicates that even where dangers were well known (for example, arsenic), disposal was not necessarily handled so as to protect either nineteenth-century workers or future generations.

1.6 Current Understanding

Is the problem well known today? Is research underway or have action programs been initiated? Since the mini-assessment is intended to alert EPA to previously unforeseen problems and to assist in research and development (R&D) and assessment planning, the emphasis is on identifying possible problems, whose existence is not proven and where the probability of occurrence may in fact be low. There is less emphasis on summarizing the state of knowledge where problems are already well recognized and research or action programs have begun, e.g. acid mine drainage. It was chiefly this criterion that guided the change of focus of the mini-assessment from public technology and public works systems to industrial technology.

2.0 PUBLIC POLICY FACTORS

2.1 Assistance to EPA's Hazardous Wastes Effort Under the Resource Conservation and Recovery Act (RCRA)

The RCRA is aimed implicitly, if not explicitly, at results of the chemical revolution in industry since the 1950's. However, the effects of toxic substances are equally undesirable whenever they may have originated, and corrective measures may be indicated for old hazards as well as new. It is also possible that the study could reveal new sources and avenues for such substances that should be included in the regulations to protect human health and the environment from the improper management of hazardous waste. This criterion reemphasized the focus on toxic substances that resulted from Criterion 1.2, persistence.

2.2 Relevance to Other EPA Responsibilities

The broader objective of OSASS's mini-assessment program, and of the retrospective forecasting efforts, is to assist R&D planning, which in turn supports all EPA program areas. Some areas of concern are relevant to EPA's air, water, and solid waste programs.

2.3 Relevance to National Objectives and Priorities

Special attention was directed to problems that might emerge because of, or prove to be unforeseen constraints on, activities associated with economic, energy, and other national objectives. Current economic policies point to reindustrialization and reurbanization (including rehabilitation of buildings, reconstruction of industrial facilities, or reclamation of land). Energy conservation policies stress recycling and repair. Energy development policies include rehabilitation of small-scale dams and hydropower facilities, and revitalization of the coal industry. Restoration, rehabilitation, reclamation, recycling, reurbanization, and reindustrialization may all bring old contaminants to the surface or impose special risks on workers carrying out these activities.

2.4 Possibility of Lessons Learned

Mistakes made in the past may have been socially forgotten as industries became obsolete or technologies were replaced by newer methods. In some cases we are now seeking to revive these industries or technologies such as wood and coal combustion and small-scale hydropower, windpower, and some other forms of "appropriate technology." It would be well to reexamine them for detrimental impacts that may have slipped from societal consciousness.

2.5 Need for Immediate Research, Management, or Mitigation Actions

First priority for assessment should of course go to problems where the need for corrective action is suspected or is possible.

3.0 RESEARCH FACTORS: AVAILABILITY OF INFORMATION

Because of the limited resources of this study, in selecting topics for case studies it was necessary to choose topics for which secondary bibliographic material could be found. However, in refining our topic list, we did not necessarily discard topics for which we could locate little information if there was some reason to suspect a need for further assessment. These topics could in fact be the ones about which further information is most needed. Therefore, we recognize that on further assessment some of the suggested topics may well be shown to entail no significant risks or problems. We have tried in some cases to indicate sources of primary data for further research.

4.0 CANDIDATES FOR FURTHER ASSESSMENT

In this section we briefly describe materials, technologies, industries, or types of structures that appear to merit further consideration. These are topics that survived our initial sorting, based on scanning available literature and applying our criteria in staff and consultant workshops (see Table 4-1).

From this longer list of topics and from the application of our criteria (Table 4-1), we identified the following as of particular concern:

Arsenic
Asbestos
Cyanides
Lead
Mercury

Electroplating industry
Iron and steel industry
Tanning industry
Coal industry
Dams and sediments
Canals (containing wastes)

From these we selected arsenic, the coal industry, the iron and steel industry, and dams and sediments for greater attention through case studies (see Section 5). Arsenic was chosen as exemplary of toxic substances used in a variety of industries. Coal is expected to have a resurgence of utilization, and under some circumstances could regain its nineteenth-century preeminence as a supplier of energy. The iron and steel industry also is a primary target for reindustrialization or modernization in the near-term future, and there is a real possibility that either demolition or repair and rebuilding of the industry's facilities could bring old wastes to the surface. Old dams are of particular interest at present for two reasons. First, there is the question of structural safety and the environmental problems associated with either failure or repair. Secondly, there is an active program of rehabilitating old dams for hydropower development.

The descriptions of assessment candidates below indicate some of the environmental and public health problems associated with these topics that appear to merit further study. The longer case studies in Section 5.0 go a step further in scoping problems for detailed assessment and could provide the basis for field studies.

In Section 4.2, we discuss other assessment candidates in the category of public technology or urban systems. In addition, we recommend that scoping and problem definition studies be performed for the other topics on our high-priority list: the electroplating industry, the tanning industry, asbestos, lead, mercury, and abandoned canals. (See Table 4-1) Of these, we suggest that the last three are of special importance.

TABLE 4-1

Candidates for Further Assessment

High Priority	Medium Priority	Low Priority
Lead	Asbestos	Lye
Mercury	Cadmium	Radium
Electroplating Industry	Sulfuric Acid	Bleach Industry
Tanning Industry	Explosives Industry	Fertilizer Industry
Canals	Hat-making Industry	Wells
	Underground Urban Networks	
	Cyanides	

4.1 INDUSTRY SECTOR CANDIDATES

4.1.1 SUBSTANCES

Asbestos

Asbestos is the popular name for several fibrous minerals used as fireproofing and heat insulating materials. Commercial asbestos is usually a variety of serpentine called chrysotile. Asbestos fibers when inhaled may cause respiratory diseases or cancer, which may not be evident for 20 to 30 years.[2] There are three sources of persistent problems to consider: mines, industry wastes, and finished products.

At the turn of the century there was little asbestos mining in the U.S. In 1902 there were two mines, in Georgia and Massachusetts. The U.S. imported most of its asbestos from Canada, where the first commercial asbestos mine was opened in 1879 in Quebec.[4] Today, Arizona and Vermont have asbestos mines.

By 1910, world production of asbestos reached 30,000 tons.[5] Asbestos was incorporated into construction materials, combined with plaster and cement, and used in pipes, floor tiles, cloth, theatre drapery, rope, felt boards, etc.[6,7]

Evaluation: high risk; high persistence. Dispersion widespread for industry and products, mining rare. Moderate capability for transport. Historically, risk known but relatively uncontrolled. Current awareness high but old sources little known. Covered by Resource Conservation and Recovery Act (RCRA). Relevant to other EPA programs. High likelihood of current and future re-emergence. Primary data not sought, secondary information scanty. Need for further assessment: moderate.

Cadmium

Cadmium is a chemical element, a silver white metal, abundant but always associated with zinc. Its vapors are highly toxic. In the nineteenth-century it may have been used or associated with smelting, electroplating, and glass and paint making. However, it appears to be chiefly a twentieth-century problem. It is currently presenting problems in disposal of sewage because automobile tires, as they wear down, leave traces of cadmium on roadways. This is washed down storm drains. Because it cannot be neutralized, treated sewage cannot be used as fertilizer.

Evaluation: high risk, high persistence. Little known about dispersion (19th century). Likelihood of transport high. Low historical awareness, moderate current awareness. Covered by RCRA. Medium priority for assessment.

Cyanides

Cyanic acid and related compounds are widely used in industrial processes and are highly poisonous. One of the first commercial examples was potassium ferrocyanide, which was originally made in 1834; later examples were potassium cyanide and ferricyanide. In the 1800's such compounds were used for Prussian blue and in calico printing, dying, case-hardening iron, and making white gunpowder and pyrotechnics.[9].

Potassium cyanide is a powerful reducing agent and was used in assaying and metallurgy, as a cleaner for silver, and in photography, dyeing, and electroplating, and also in extracting gold from ores.[10]

Evaluation: high risk, high persistence. Moderate to high dispersion, capable of transport. Historically recognized but uncontrolled, now controlled but old sources not identified. Covered by RCRA. Relevant to other EPA program. May re-emerge. Priority for further assessment moderate. Primary data not sought, secondary data scanty.

Lead

Lead is a chemical element, a white to bluish grey metal, and one of the four most highly utilized metals. It is highly toxic. Lead poisoning or plumbism is caused by inhaling or ingesting particles.[11] In the late 1700's in England, Sir George Baker first identified a condition commonly called "Devonshire colic" as lead poisoning caused by lining cider presses and vats with lead. This was probably the first study of toxic substances in commerce. In 1726, Boston passed a law forbidding use of lead in distilling rum (probably the first U.S. environmental safety law).[12] About the same time, Benjamin Franklin published a book by Thomas Cadwaldor on "lead colic and lead palsy."[13]

In the early 1900's, Dr. Alice Hamilton, a member of a special Illinois commission, performed a study that was a major milestone in occupational health and safety. She identified 35,000 cases of lead poisoning that occurred from 1908 to 1914.[14] It is fair to assume that industries not sensitive to hazards from lead within the factory were also not attending to the fate of lead wastes outside the factory, or to hazards of lead in their products.

In 1904 the connection was first made between lead poisoning in children and the little understood habit of eating paint chips.[15] Lead paint also tends to dry and chalk as it ages, producing dust that can be inhaled.[16] Lead paint was widely used until about 1940 and lead was not banned as a drying agent until the 1970's.[17]

Lead was used in many nineteenth-century products. Lead arsenate was the most popular pesticide until the advent of DDT. Concern about this pesticide centered on the arsenic content (see Section 5.1) and not until the 1920's were questions raises about the hazards of the lead.[18] Lead was also used in water pipes, which can corrode and introduce lead into water supplies. Most available information indicates that little lead piping is left in houses[19] but there is still some between water mains and houses in old cities and farms.[20]

Lead was also used in making rubber, bullets, and type, and for ceramic glazes which were used on eating and drinking utensils in some cases. It was also used in or associated with electroplating, the making of artificial flowers, dyes, glassmaking, jewelry making, match manufacture, metal working, plumbing, scrap metal recovery, and tanning.[21]

In 1902, there were lead and zinc mines in the following states: Arizona (1), Colorado (3), Illinois (14), Iowa (14), Kansas (57), Kentucky (1), Missouri (374), New Jersey (1), New Mexico (1), New York (1), Wisconsin (90), and Virginia (62), a total of 619 mines in 12 states.[22]

Evaluation: high risk, high persistence, high dispersion, high probability of transport. Risk known but relatively uncontrolled in nineteenth-century; now known and managed. Covered by RCRA and of interest to other EPA programs. High probability of re-emergence. Primary and secondary data probably adequate for assessment. High priority for further assessment.

Lye

Lye is the common term for strongly alkaline substances such as sodium hydroxide or potassium hydroxide, used in making soap or as a detergent. Originally "lye" was produced by leaching wood ashes. Such substances are dangerous but are highly reactive and thus would not have survived the passage of time.

Evaluation: high risk, very low persistance. Not on RCRA. No further assessment warrented.

Mercury

Mercury is a chemical element, a silver white metal, liquid under standard conditions, often referred to as quick-silver. It was mined as early as 500 B.C., and occurs widely, but present production is dominated by Italy and Spain and about half of that produced is imported into the U.S. It is highly toxic.

Mercury is volatile and tends to concentrate in the atmospher. In water it is readily transformed into methyl mercury and absorbed by fish, and later taken in by humans who eat the fish. Inhaled mercury vapor is almost completely absorbed and distributed throughout the body. Chronic exposure has effects that act on the central nervous system causing sensory disturbances and neural degeneration. Inorganic mercury accumulates in kidneys causing renal toxicity. However methyl mercury is the most serious hazard since it is readily absorbed.

When high levels of mercury were discovered in swordfish (and other fish) in the 1970's, public alarm seriously damaged the seafood industry. It is not yet clear whether human activities are responsible for most of the mercury contamination of the oceans or whether much of the mercury comes from natural sources--the issue is still highly controversial. Some tests concluded that "ninety-year-old specimens of tuna have been found to contain mercury levels similar to those found in modern fish"[23] - note, however, that this does not rule out the possibility of anthropogenic sources. Some experts believe that mercury residuals from human activities have not reached harmful levels in the general environment. In Minamata Bay, Japan, however, industrial emissions of mercury caused an epidemic of poisoning, birth defects, and still births in recent years.[24]

In the nineteenth-century mercury was used extensively in the making of felt hats (see Section 4.1.2 below) and in other industries such as ceramics, drugs, dyes, electroplating, explosives and fireworks, tanning and fur working. Its use increased in the late nineteenth-century because of the new chlorine (caustic soda) industry.[25] Mercury was a product of the refining of gold and silver and was released through coal combustion.[26]

In 1902, there were 36 mines in California and five in Texas producing mercury.[27]

Evaluation: high risk, high persistence, high dispersion of industry and products, regional concentration of mining wastes, high capability of transport. Known (to some extent) but poorly controlled in nineteenth-century; high awareness and control currently. Covered by RCRA, relevant to other EPA programs. High likelihood of re-emergence. Primary data not sought, secondary data scanty. High priority for further assessment.

Radium

Radium is a chemical element, a white metal, which is rapidly oxidized in air and evolves heat continuously. It is formed by radioactive transformation of uranium, and spontaneously generates radon gas.

Rontgen and Becquerel experimented with radioactivity in the last decade of the nineteenth-century, but radium was first separated and identified as an element by Marie Curie in 1910. Radium was then used commercially for luminous paints and varnishes, and during and after World War I, the element was linked to poisoning in watchface painters, who licked their paintbrushes to make a fine point in painting the numerals.[28]

Evaluation: radium should be considered a twentieth-century hazard, and is not further considered in this study.

Sulfur and Sulfuric Acid

Sulfur, a chemical element, is found in nature both in a free state and as a variety of sulfide and sulfate minerals. There are great deposits in Louisiana, Texas, California, Colorado, Wyoming, and Nevada.

According to the 1905 Census of Manufactures, "sulfuric acid... is so extensively used in the manufacture of other chemical products that the statistics of its production have been regarded as a safe criterion by which to gauge the activity of a country in chemical manufacturing."[29] It was then obtained from brimstone, burning pyrites, roaster gases in zinc and copper smelting and recovery from spent or sludge acid, as well as from mining. It was also obtained from gas, soda, and ammonia works and byproduct coke ovens (see Section 5.3).[30]

Sulfur was used in the preparation of a wide variety of other chemicals and industrial materials: it was essential to the metallurgical industries and also used in manufacturing starch, sirup and sugar, and liquor, and in the paper industry.[31] However, sulfur and sulfuric acid was and is a pollutant as well. Much sulfur was released in smelter smoke (one smelter giving off many thousands of tons of sulfur compounds annually).[32] Table 4-2 indicates major uses of sulfuric acid in 1905.

Sulfur-related gases (e.g., sulfur dioxide, sulfuric acid vapor) are highly dangerous in high concentrations but there are no recognized dangerous effects from low-level chronic exposure.[33] Sulfuric acid would have dissipated from land dumps, or been diluted and dissipated in streams. Currently, there is much concern about "acid rain" - as a result of atmospheric sulfuric acid from automobile emissions and coal-burning power plants. Some experts contend that some of the supposed environmental effects, in particular some of the lakes rendered sterile by anthropogenic acidity, are in fact affected by "natural" acidity resulting from vegetation such as oak trees. A recent article in Science magazine noted, in defense of this argument, that "some lakes are known to have been acidic since 1860."[34] The implicit assumption was that this acidity therefore could only have been "natural." However, it is conceivable that nineteenth-century wastes and residues, embedded in sediments or leaching from long-forgotten industry sites (even small smelters, forges, or tanneries) could be contributing to this acidity. This possibility suggests a need for further assessment.

Evaluation: Moderate risk, presumably low persistence (but this can be questioned), very wide dispersion of industry wastes and products, moderately wide dispersion of mining. High capability for transport. Historically uncontrolled, currently well known and managed. Little awareness of widely dispersed old sites. Re-emergence uncertain. Primary data poor, secondary data poor. Generally low priority for further assessment, but note special circumstance described.

4.1.2 INDUSTRIES

Bleaching

The wide field of chlorinated hydrocarbons today provides some of our most toxic chemicals, but these have largely been developed since World War II.[35] Although the use of chlorine as a bleach was known in the eighteenth-century, it was not widely processed until the end of the nineteenth-century, when it was just beginning to be used as an agent in water supply treatment.[36] Other bleaches used in the 1800's were hydrogen dioxide (peroxide), sodium, magnesium, calcium, and barium salts; sufurous acid; and other sulfites.[37] They are generally toxic in concentration but not persistent. The number of establishments exclusively producing bleaches was five in 1900 and nine in 1905; those producing bleaches as a byproduct numbered 26 in 1900 and 33 in 1905.[38]

Evaluation: moderate risk, very low or no persistence, need for further assessment not indicated.

Electroplating

The ability to coat an object with gold, copper, or silver held in solution, by passing an electrical current through the bath, was developed in the early 1800's.[39] It became commercially successful in the second half of the century when silverplating became economically feasible partly due to the discovery that potassium cyanide was the best agent for the solution.[40] Silverplating became very popular in America.

Electroplating establishments may have used a variety of acids and alkalis, including chromic acid, potassium cyanide, zinc cyanide, and zinc chloride, as well as using lead, copper, silver, and gold.[41] The cyanides, zinc chloride, and lead are toxic and persistent. Gold and copper would probably have no significant environmental or health effects; silver causes discoloration of body tissues but is considered benign.[42]

In 1905, there were 229 electroplating establishments, largely concentrated in New England.[43]

Evaluation: Wide variety of toxic substances, high persistence, generally capable of transport. Regional concentration of residuals. Little regulatory control, varying awareness of risk in nineteenth-century. Current knowledge and control adequate. Many materials covered by RCRA and of interest to other EPA programs. Likelihood of re-emergence high. Primary and secondary data scanty. High priority for further assessment on regional basis.

Explosives

Gunpowder has been manufactured in Europe since the battle between French and English knights at Crecy in 1346. It is composed of varying proportions of potassium nitrate, charcoal, and sulfur. In the 1800's, the potassium nitrate was prepared from sodium nitrate (from India and later Chile) and potassium chloride.[44] The production of nitroglycerine in the U.S began in 1867. It used glycerin and sulfuric and nitric acides.[45] Nitroglycerine is used for treatment of coronary disorders.

Another form of explosive was gun cotton, a form of cellulose that was nitrated by a mix of sulfuric and nitric acids and cellulose,[46] and cellulose, which is also the basis for celluloid. Nobel invented dynamite in 1866; its manufacture in the U.S. was first noted in the Census of 1880. It was a rapidly growing industry however. In 1890, 30,626,738 pounds of dynamite were made, in 1900, 85,846,456 pounds were made.[47]

Blasting caps were made with mercuric fulminates manufactured from grain alcohol, mercury, and nitric acid. Most of these fulminates however were imported.[48]

TABLE 4-2

Quantity of Sulfuric Acid Consumed for Specific Purposes:

1900

	Tons
Total domestic production	1,548,123
Purposes for which consumed:	
Fertilizer manufacture	803,358
Petroleum refining	181,782
Pickling iron and steel	125,000
Alum manufacture	71,426
Mixed acids manufacture	63,059
Textile industry	50,000
Muriatic acid manufacture	48,750
Nitric acid manufacture	47,348
Acetic acid manufacture	17,814
Ammonium sulfate manufacture	13,908
Explosives manufacture	13,500
Blue vitriol manufacture	10,645
Epsom salt manufacture	2,773
Storage batteries	2,640
Tartaric acid manufacture	1,503
Iron liquors manufacture	1,220
Boric acid manufacture	707
Zinc sulfate manufacture	415
All other purposes	92,275

SOURCE: U.S. Bureau of the Census, Special Reports, Manufactures, 1905 (U.S. Government Printing Office, 1908), Part IV, p. 411.

The toxicity of mercury compounds have been noted. Nitroglycerine is unlikely to have survived, although any explosives left from the nineteenth-century would be highly sensitive and dangerous.

Evaluation: Moderate risk, moderate to low persistence of some materials. Industry was not widespread. Medium priority for further assessment.

Fertilizers

In the first half of the 1800's, organic matter such as fish was used for fertilizer. By the end of the century a good deal more was known about the promotion of plant growth. Increased efficiency in mechanization allowed other organic substances such as dried blood from slaughterhouses to be used.[49] The first chemical fertilizer manufacturing plant was opened in 1850.[50] The importance of phosphoric acid was soon realized and the U.S. imported a large part of of Peru's guano harvest.[51] The apparent exhaustion of that resource provided the impetus for developing phosphate mines in the U.S. In 1902 they were mines in Arkansas, Florida, Pennsylvania, South Carolina, and Tennessee, and the fertilizer industry was centered in the southern United States.[52] Phosphate was later extracted from the slag of open-hearth furnaces.[53]

Phosphorus compounds can cause skin burns; they can be inhaled, taken in through the skin, or ingested. Acute exposure can cause severe or fatal reactions, and chronic exposure is also serious.[54]

In 1900, 2,887,004 tons of fertilizer were made in 422 establishments. In 1905, 3,591,771 tons were made in 400 establishments. As noted these were concentrated in the south.[55]

Evaluation: Moderate risk, low persistence; regionally concentrated mining and manufacture, moderately dispersed use. Low priority for further assessment.

Hat Making

Hats were important in the late nineteenth-century--"millinery, custom work" was the eighth largest industry in terms number of establishments in 1900.[56] A great many hats were made of felt (sheep's wool, often mixed with fur or hair). The manufacture of felt for hats required that pelts first go through a chemical process called carroting, which involved mercuric nitrate in acid solution. When this was completed, the wool or fur contained two to three percent mercury, one third of which was released into the air during a further manufacturing process. In addition, the soaked wool or fur had to be aged for six months to a year, so there were high inventories of pelts containing mercury stored in the factories.[57]

Both acute and chronic exposure to mercury, as noted above, have severe effects, the classic symptoms of which are gingivitis, tremor, and emotional instability. Chronic mercuric poisoning in hatters gave rise to the term "mad as a hatter," and is also the inspiration for the "Mad Hatter" in Alice in Wonderland.[58]

Although long recognized this occupational health hazard was only eradicated in the 1950's with the development of new compounds.[59] The effects on hat wearers of the mercury remaining in the felt hats are unknown; the current fashion for "antique clothes" could bring about some new exposure.

Evaluation: Risk high (mercury residuals), high persistence; dispersion and location unclear, capability for transport moderate. See "mercury" above for further evaluation. Some potential for re-emergence from reclamation of old buildings. Medium to low priority for further assessment.

Pharmaceuticals

The great blossoming of chemically synthetic drugs occurred in the twentieth century. Until the end of the nineteenth-century, most drugs were derived either from minerals or plants."[60] Organic materials in general would not be persistent. Mercury and Arsenic, often used in medicines, are discussed elsewhere (see Section 4.1.1 and Section 5.1). Coal tar drugs began to develop about 1880 but were largely manufactured in Europe.

Evaluation: Risk low to high, but generally limited persistence. Dispersion or concentration unclear, re-emergence of low probability. Low priority for further assessment.

Tanning

"Tanning" is the treatment of animal skins to make them resistant to decomposition, flexible, and soft; in other words, to make skins into leather. The name comes from "tannin," substances found in many plants and generally related to phenols. Tannin, and tanning, were known to the Indians before Europeans came to America, and tanning had been practiced far back in history, probably originating in China.

The leather tanning, currying, and finishing industry was widespread in the 1800's but was consolidating during the decades around the turn of the century. In 1880, there were 5,628 establishments, in 1890 there were 1,787, and in 1900 there were 1,306 (there may be some double counting in the first figure since some establishments did only tanning and some only currying (preparation for tanning).[61] The consolidation was due in part to more efficient machinery and to the introduction of electricity. By 1905 the number was down to 1,049, but these were very widely dispersed:

Alabama	4
California	49
Colorado	1
Connecticut	9
Delaware	20
Georgia	29
Illinois	28
Indiana	13
Iowa	2
Kentucky	20
Louisiana	1
Maine	27
Maryland	17
Massachusetts	132
Michigan	25
Minnesota	9
Mississippi	2
Montana	9
New Hampshire	8
North Dakota	1
New Jersey	73
New York	118
North Carolina	34
Ohio	40
Oregon	11
Pennsylvania	205
Rhod Island	6
South Carolina	3
South Dakota	1
Tennessee	29
Texas	5
Utah	1
Vermont	4
Virginia	44
Washington	3
West Virginia	33
Wisconsin	33

SOURCE: U.S. Bureau of the Census, Special Reports, Manufactures 1905 (U.S. Government Printing Office, 1908), pp. 278, 284.

Philadelphia was the leathermaking capital of the world.[62] For most of the 1800's, tanning was done with tannin from hemlock bark, oak bark, chestnut bark, and wild sumac.[63] From 1885 on, however, tanning was being done with inorganic chemicals like alum, aluminum sulfate, aluminum acetate, chromates and chromic oxides, hyposulfite of soda, muriatic acid, sulfuric acid, ferric salt, and common salt.[64]

Before the tanning was done, the flesh was scraped off and the hair soaked off. Lime was the best depilatory, sulfide of sodium and sulfide of arsenic had also been tried but worked best in conjunction with lime.[65] The hair and animal wastes created solid waste in water systems and noxious smells. Once the leather had soaked in its tanning liquor and had been dried, it was "stuffed" with fats to make in pliable. The materials used were cod liver oil, neat's foot oil, degras, tallow, stearin, paraffin wax, glycerin, etc. Boras, sal soda, soaps, and other alkalis were used for cutting these oils and fats.[66] Finally, the leather was dyed, often with aniline or coal tar colors because they did not require mordants, acids, or salts to make the leather more absorptive.

Many of the materials mentioned are both toxic and persistent (chromates, arsenic etc.). Coal tar dyes also contain carcinogens. The pathology of alumina compounds is uncertain.[67] Tanneries usually dumped their wastes on the ground or into streams, and their interactions in the environment are also poorly studied.

Evaluation: risk moderate to high, persistence high, dispersion high, transport capability high. Risk uncontrolled in nineteenth-century, residual risks unrecognized or poorly recognized now. Likelihood of sporatic re-emergence high. High priority for further assessment. Primary and secondary data scanty.

4.1.3 STRUCTURES

Canals

The environmental hazards posed by dumping or depositing toxic wastes in canals was vividly demonstrated by the results of Hooker Chemical Company's use of Love Canal in Niagara Falls, N.Y., as an imperfectly-sealed, toxic waste dump.[67] The canal itself was built in the 1890's, but it was used as a dump in the 1930's and 1940's.[68] Other canals may well have been used earlier as repositories for toxic wastes, including wastes from the nineteenth-century. Wastes were routinely poured into water bodies, which were considered capable of purifying themselves. Solid wastes may have been used deliberately as fill for abandoned canals. Nineteenth-century wastes often included arsenic, lead, mercury, and other persistent toxins.

The heyday of canal building in America was in the first half of the nineteenth century. In response to transportation needs generated by the blossoming Industrial Revolution, extensive canal systems were planned, and many were actually completed. However, the rapid expansion of the railroad as a faster and more flexible mode of transport soon made canals obsolete. It is difficult to discover what then became of the canals on a national scale. Some were abandoned; in some cases they were probably filled in--with what is seldom known. Others, like the Erie Canal and the C&O Canal, have been kept open. Inter-urban canals, especially in cities like Milwaukee and Lowell, Massachusetts, are most likely to contain problems.

Determining the condition of the nineteenth-century canals may require research at the local level in numerous communities. However, much information may be available from local historical associations.

Those canals not filled in may also have toxic materials in their sediment, since it is probable that they served as waste flushing systems before or since they were abandoned.

Evaluation: high priority for assessment.

Underground Urban Networks

Few communities have conducted comprehensive studies on what lies beneath their buildings and roadways. Consequently, there is little knowledge of what underground structures actually exist and/or which of them could be creating problems. Urban underground systems include electrical wiring, water pipes, sewage systems, gas lines, and subways. In general, each system is maintained by a different utility or other entity so that there is very little coordination and pooling of information regarding what lies underground. It is common, moreover, for a section of road to be plowed up while subway construction is underway, to be repaved, and within a matter of weeks or months, to be dug up again while water or electrical maintenance is done.

Because so little thorough research has been done, it is not known to what extent underground networks of the nineteenth-century may still be in place and in what condition they are now. In some cases, such as sewers, these systems have been incorporated into networks in use today (see Section 4.2).

However, a number of nineteenth-century technologies that required networks of piping and wiring are gone, and these systems may have been abandoned. Examples are pipes used to distribute coal gas used as an illuminant, pneumatic tubes used to transport mail, underground trolley wires, pipes for natural gas as a heat source, other lead pipes, and in some cases telephone and telegraph wires.

Potential hazards of these systems, especially those that contained a combustible or chemical substance, have never been satisfactorily assessed. Systemic failures of sewer lines, or toxic substances entering leaky water mains, are especially likely to cause problems.

Wells

Wells, septic systems, or privy vaults were, of course, widely employed during the nineteenth-century until and during the transition to community water systems. The ramifications of their continued existence are unknown. As with canals, the presence of abandoned wells raises questions about possible subsidence and collapse, their use as dump sites, and the adequacy of their casings. In addition, by the 1930's wells were being dug for the purpose of receiving industrial wastes. This topic is even less researched and far less readily "researchable" than that of canals.

4.2 PUBLIC WORKS

The Department of Housing and Urban Development's Office of Policy Development and Research is carrying out a major study of capital investment requirements in major urban areas of the United States. As part of this study, the Urban Institute has prepared reports on the future of the capital plant of six cities: Boston, Cincinnati, Cleveland, Dallas, New York, and Oakland. The inventory of capital investment requirements necessarily assessed some of the problems arising from aging public works. With most of these problems now identified, various research and action programs are addressing them further. This mini-assessment, therefore, focused primarily on industrial technology as a possible source of future environmental problems.

This section, however, presents a brief overview of the candidates for further assessment of future environmental problems arising from nineteenth-century public works. In general, these are urban systems. Rural areas have relatively few publicly-owned systems dating from the nineteenth-century. Because of the movement of population during the 1970's toward smaller towns and rural areas, the Farmer's Home Administration has initiated a National Rural Communities Facility Assessment study, which is still in the problem definition phase. It will focus on the needs of small towns for 32 essential facilities, including public works, health care, and fire protection. This may provide a source of further information on environmental implications of surviving nineteenth-century public technology in rural areas.

The criteria we suggest for use in choosing public technologies for assessment are listed below. Technologies should be assessed which:

- Were put in place in many areas during the last half of the century,
- Are still in use (at least part of the original system) today,
- Served functions essential to maintaining an acceptable urban environment under modern conditions of building and population density,
- Were relatively inaccessible (e.g., underground) or were linear (crossing jurisdictional boundaries) and so might be poorly maintained,
- Had received little maintenance and only sporadic upgrading,
- Might have a finite "lifetime" that was perhaps not well specified or understood,
- Have been subjected to environmental stresses not foreseen at the time they were built, such as modern pollutants and corrosives and increased weight loads,
- Might have serious environmental, health, or safety impacts if they failed progressively or abruptly,
- May be costly, cumbersome, or dangerous to dispose of when replacement is necessary,
- Would be costly, difficult, or dangerous to repair or rehabilitate.

A number of technologies or systems were initially targeted as meeting some or all of these criteria: roads, bridges, tunnels, railroads, dams, water lines, sewage lines, electric lines, gas lines, telegraph lines, telephone lines, etc. However, after an initial literature survey, a number of interviews with experts, and a discussion with OSASS staff, no further investigation was carried out in the present study.

WATER AND SEWER LINES

Water and sewer lines in urban areas tend to be poorly maintained because they are underground and their deterioration is not highly visible. Those in charge of city budgets have tended to cut back on maintenance in favor of allocations for more visible public projects, such as hospitals, streets, and schools. The failure to maintain water and sewage systems is a nationwide problem and touches both new and old cities. It is, of course, the older cities that have more extensive problems.

There has been no nationwide survey of the conditions of sewer systems. Many cities themselves have poor data about their system and even poor maps of it. The city sanitary engineer is generally a good source of information on sewer conditions and breakdowns, but this information may erode over time as personnel change.

Sewer systems were installed in many American cities during a very brief period in the last half of the nineteenth-century. The first were in Brooklyn (1855) and Chicago (1856). By 1880, 102 of the existing 222 cities had sewage systems, and by 1909 there were 25,000 miles of sewers in cities over 30,000 people. Extensive research into the history of nineteenth-century sewage systems has been conducted by Prof. Joel Tarr at Carnegie Mellon University. Originally, most of the pipes were wooden; some of these are still in use, for example, in Boston. For the most part, however, the pipes are iron, which has resulted in the build-up of iron oxide inside the pipe (tuberculation). This build-up then reduces the capacity of the pipes. Tuberculation can be alleviated by the current practice of lining pipes with cement; also, machines have been developed that can line old pipes in situ.

The common problem faced by older cities with pipes is leakage or bursting. During storms this can result in flooded basements and streets. In general, this is considered a nuisance problem but not a health problem. The solution has been to replace the faulty pipe. There is little possibility of an "epidemic" breakdown by all nineteenth-century pipes reaching the end of their normal lifespan in a short time, since the long-term pattern has been the occasional breakdown of one section after another and its replacement by new pipe. However, the rate of necessary replacement speeds up with aging.

The major problem is that of financing repairs. Controversy has arisen over whether the costs of the failure of a city to maintain its infrastructure or capital stock should be paid for by the Federal government. The massive amounts of money needed are far beyond many cities' funding abilities (particularly those cities that have a declining population and tax base); this has perforce made the help of the Federal government essential. For example, it is estimated by the Urban Institute that it would take Cleveland $700 million to upgrade its infrastructure; at $40 billion, New York's would be the most expensive. Government officials from eleven Northeastern states estimated they would need in all $25 million for their sewage systems.

A further question arises because of the nature of the systems that were installed by larger cities in the nineteenth-century. For the most part, they chose a sewage system that combined drainage of sewage with storm runoff, as opposed to separate sewage and storm systems. Although this was considered the better choice in the 1800's, it means that in today's larger cities, a heavy rainfall often taxes the pipes beyond capacity and raw sewage overflows into the disposal system without treatment. Many of the cities on Lake Erie, for example, have combined systems. The result is that unless those systems are replaced with separate sewer systems, Lake Erie may never be completely cleaned. The cost of converting any public works system, even though the replacement might be more efficient, could probably not be borne by a city alone.

Many experts believe that the best way to manage water and sewage systems is to put them under regional authorities. The city of Cleveland, in 1978, was ordered to place water control in a regional authority in order to improve its management.

It is likely that aging cities will need to patch their leaking systems at ever increasing rates. The capital needed to upgrade an entire municipal system or to replace it with the most efficient technology under regional control prohibits a city from taking action without Federal aid. Some steps have been taken in this direction. In addition, Senators McGovern and Javits introduced S.1049, the Community Conservation Act of 1979, which proposed the creation of a National Bank for Community Conservation. The bank could grant up to $5 billion in loans to local governments to repair aging structures. The bill was sent to the Banking Committee on May 1, 1979, but no hearings on it were held.

ROADS AND BRIDGES

A major problem with roads today is maintenance of their pavement. Much paving was done at the turn of the century. Bicycles became very popular, and bicyclists protested at cobblestones, they wanted asphalt, which had come to be produced in adequate quantities. The second large wave of paving came in response to automobile traffic in the 1920's. Today, the repair of potholes is a major budget item for all cities and counties. The adequacy of rural roads to support traffic associated with domestic energy development (e.g., large coal trucks, oil shale carriers, etc.) is now in question.

The ecological impacts of the use of salt to clear roadways of ice and snow are probably severe and have received little attention. Runoff from urban paving containing lead, cadmium, and other toxic substances is a major factor in pollution of soil, streams, and groundwater.

Safety problems result from the mismatch between nineteenth-century roadway engineering and the size, weight, and speed of modern vehicles.

Bridges and their deterioration are very serious problems. Many of these bridges, however, were built after increased automobile usage in the 1920's and as a result of New Deal funding in the 1930's, rather than in the 1800's. In general they have a normal lifespan of 40 to 50 years, which explains the massive bridge repair problem currently facing the nation. A much smaller number of bridges was built in the 1800's, but these include some important ones such as the Brooklyn Bridge, built in 1883.

In order to assess how much money will be needed to upgrade bridges both locally and through the Federal aid system, a National Bridge Inventory was ordered by the Secretary of Transportation. All bridges were to be inspected and classified according to their rate of deterioration by December 31, 1980. The Washington headquarters of the Federal Highway Administration, which is implementing this inventory, projects that 181,000 bridges are structurally deficient or functionally obsolete. The total cost to repair or replace the bridges is estimated at $33.2 billion. The allocation of funds for repair does not appear to be adequate (the discretionary fund for FY 1980 was $200 million). It is uncertain what the environmental/ecological impacts of bridge repair projects will be, but they are likely to be transitory in most cases.

TUNNELS

Most tunnels were and are built as part of the water, sewage, electric, and gas systems and are therefore maintained by the authority responsible for the rest of the system. Tunnels for transportation are owned and repaired either by railroad companies or by highway departments. Many railroad tunnels were built in the mid- and late nineteenth-century, but the first major tunnel for automobiles was New York's Holland Tunnel, built in 1927. Highway tunnels are not a nineteenth-century technology.

RAILROADS AND RAILROAD TRACKS

These are not public works because each railroad company is responsible for maintaining its own track. According to the Association of American Railroads, "Any track which was laid in the 1800's has by now been replaced."

ELECTRIC, GAS, TELEPHONE, AND TELEGRAPH LINES

A majority of these lines are owned and maintained by private companies; some are part of municipal (and county) utilities. Federal electric facilities (associated with hydroelectricity) were built in the twentieth-century. These utility lines generally have excellent service records, although there are occasional problems or disasters such as gas line explosions or leaks. It is not clear whether any of these lines or pipes date from the nineteenth-century, but it appears unlikely.

4.1 FOOTNOTES

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[3] U.S. Department of Commerce and Labor, Mines and Quarries 1902 (U.S. Government Printing Office, 1905), pp. 380-390.

[4] Brodeur, p. 6.

[5] U.S. Department of Commerce and Labor, p. 10.

[6] Ibid., p. 6, p. 54-57.

[7] U.S. Department of Commerce and Labor, p. 973.

[8] Schroeder, Henry A., The Poisons Around Us (Indiana University Press, 1974), p. 23, and Omang, Joanne, "U.S. Faces the Problem of Disposing of the Undisposable," Washington Post (March 14, 1980).

[9] U.S. Bureau of the Census, "Manufactures," Twelfth Census 1900, Part IV, p. 553.

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[12] Sax, p. 3.

[13] Ibid.

[14] Ibid.

[15] Needleman, Herbert L., "Lead Exposure and Human Health: Recent Data on an Ancient Problem," Technology Review, Vol. 82, No. 5 (March/April 1980), p. 41, 42.

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[20] Schroeder, p. 50.

[21] Bolles, p. 483, and Milby, pp. 170-72.

[22] Mines and quarries, 1902.

[23] Rothman, Harry, Murderous Providence (Bobbs-Merrill Co., 1972), p. 145.

[24] Schroeder, p. 60.

[25] Singer, Charles, ed., A History of Technology, Vol. III (Oxford, U.K.: Clarendon Press, 1958), p. 250.

[26] Jepson, Hans G., "Coping with Results of Mercury and Arsenic Spills," Pollution Engineering, Vol. 10 (October 1978), p. 58.

[27] U.S. Department of Commerce and Labor, pp. 380-390.

[28] Sax, p. 953.

[29] U.S. Bureau of the Census, Special Reports, Manufactures 1905, Part IV (U.S. Government Printing Office, 1908), p. 403.

[30] Ibid., p. 406-411.

[31] Ibid.

[32] Ibid., p. 408.

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[34] Patrick, Ruth; Binetti, Victoria P.; Halterman, Steven G. "Acid Lakes from Natural and Anthropogenic Causes," Science, Vol. 211 (January 30, 1981), p. 447.

[35] Interview with Robert P. Multhauf, Chemical Historian, American History Museum, Smithsonian Institution.

[36] Tarr, Joel, "Decisions about Wastewater Technology 1850-1932", Journal of the Water Resources Planning and Management Division (May 1977).

[37] U.S. Bureau of the Census, Special Reports, Part IV, p. 441.

[38] U.S. Bureau of the Census, Special Reports, Part IV, p. 441.

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[40] Ibid.

[41] Birmingham, D. J., "Occupational Dermatoses," Occupational Diseases, U.S. Public Health Service Publ. No. 1097, Gafafer, W. M., ed. (U.S. Government Printing Office, 1964), p. 35.

[42] Milby, p. 212.

[43] U.S. Bureau of the Census, Special Reports, Part IV, p. 718.

[44] U.S. Bureau of the Census, Twelfth Census, Part IV, p. 593. Also, Robert Multhary interview.

[45] Ibid., p. 594.

[46] Ibid.

[47] Ibid., p. 596.

[48] Ibid., p. 598.

[49] U.S. Bureau of the Census, Twelfth Census, Part IV, p. 561.

[50] Ibid., p. 562.

[51] Clark, V. S., History of Manufactures in the United States 1860-1914 (Carnegie Institute of Washington, 1928), p. 824.

[52] U.S. Department of Commerce and Labor, pp. 380-390.

[53] Clark, p. 825.

[54] Milby, pp. 202-203.

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[56] U.S. Bureau of the Census, Abstract of the Twelfth Census 1900 (U.S. Government Printing Office, 1902), p. 322.

[57] Encyclopedia Americana, 1969 ed., "felt."

4.1 FOOTNOTES (cont'd)

[58] See note 13, Lewis Carroll, Alice in Wonderland in Three Centuries of English Literature 1625-1900, Miller, J. E., et. al., eds. (Scott, Foresman and Co., 1976), p. 459.

[59] Encyclopedia Americana, 1969 ed., "felt."

[60] Encyclopedia Britannica, 1964 ed., "chemotherapy."

[61] U.S. Bureau of the Census, Abstract, p. 312.

[62] Clark, p. 466.

[63] Ibid., p. 463.

[64] U.S. Bureau of the Census, Special Reports, Part III, p. 274.

[65] Ibid., p. 275.

[66] U.S. Bureau of the Census, Special Reports, Part III, p. 276-277.

[67] Milby, p. 123.

[68] See Brown, Michael H., Laying Waste (Pantheon Books, 1980), pp. 517.

5.0 CASE STUDIES

This section of the report presents four case studies, or exploratory "micro-assessments" of nineteenth century sources of twentieth century problems. These were selected from our original list of candidates (the remainder of which was described in the last section) as representative of those which merit further retrospective assessment. For these four areas of concern we have carried our analysis a step further, to identify specific environmental and health hazards which need attention. They are:

- Arsenic - a toxic substance, which in a variety of compounds, was widely used in many industries and activities, and persists today in widely dispersed dumps, sediments, and slags and in old buildings and collecters items. There is already sporadic evidence that its re-emergence is causing significant health problems.
- The coal industry - which, from mining and combustion to the production and use of coal-derived chemicals was (and to an extent still is) the source of many enduring environmental and health problems.
- The iron and steel industry - which involves a comparable, and less well known, set of environmental and health concerns.
- Old dams and their reservoir sediments - which probably represent the current resting place of much of the toxic residues of the nineteenth century; residues which may re-emerge at any time as a result of dam breaching, repair, or rehabilitation and associated dredging.

5.1 ARSENIC AND OLD LACE

5.1.1 Summary

Arsenic and arsenic compounds* were extensively used in the nineteenth century as pesticides and pigments and in a wide variety of manufacturing processes and consumer products. Most Americans came in frequent contact with arsenic because of its use in wallpaper, carpets, clothing, toys, and a variety of other everyday items; and many workers were exposed to arsenic in the workplace. Symptoms of arsenic poisoning often went unrecognized, but accumulating knowledge of the effects on health gradually led to the elimination of many of the consumer-oriented uses of arsenic about the turn of the century.

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*For convenience the term "arsenic" has been used to include arsenic compounds, most commercial applications of arsenic being in the compound form. Where the distinction is important, it will be noted.

However, the generous use of arsenic may well have left unpleasant legacies for the twentieth and twenty-first centuries. Approximately 179,000 short tons of arsenic were produced in or imported into the United States between 1867 and 1918, when its use was most important (see Table 5-1). Arsenic is an element, it persists, and its toxic properties endure. Wastes associated with mining or manufacture of arsenic and arsenic compounds were typically dumped on site or into bodies of running water. In addition, much of the arsenic used in the nineteenth century may be "stored" in buildings or products that are still in use.

Nineteenth-century arsenic residues are therefore likely to be found:

- In residual mine tailings and manufacturing waste dumps close to the site of old mines and factories, either on the surface or subsurface where they may be encountered in excavation.
- In sediments in reservoirs, lakes, rivers, canals, or bays, either as a result of water-based disposal or through erosion of agricultural lands treated with pesticides.
- As a contaminant of soil and groundwater.
- As residues embedded in buildings once used for processing and manufacturing.
- In a variety of nineteenth-century consumer products still in use, being refurbished, or collected and displayed as curious or historical objects.

Arsenic is taken into the body by ingestion, through contact with the skin, or through respiration in the form of dust or arsine gas. Symptoms of arsenic poisoning may be subtle and cumulative; they can easily go unrecognized or not be associated with the source of the poisoning, especially in the case of unidentified residues of nineteenth-century applications of arsenic.

Those who may be especially at risk, therefore, include workmen excavating or reclaiming old mine or industrial sites; workmen converting industrial buildings, including city lofts, or dismantling such facilities; workmen or "home-handymen" who are renovating, remodeling, or refurbishing old residences or antique furnishings; and professionals and hobbyists who collect, repair, and frequently handle nineteenth-century artifacts. They are likely to absorb or breathe in stirred-up dust, and to absorb pigments being removed by abrasion or solvents. Table 5-2 gives a partial list of arsenic manufacturers.

Particularly in localities where there are concentrated arsenic deposits, the extent to which the general public may be at risk because of contaminated soil or

TABLE 5-1

U.S. Imports of Arsenic

Year	Pounds
1867	--
1868	1,442,142
1869	1,442,576
1870	566,500
1871	1,329,693
1872	1,109,811
1873	612,116
1874	1,636,335
1875	2,327,742
1876	447,019
1877	2,588,948
1878	2,471,861
1879	2,445,852
1880	2,717,777
1881	2,225,425
1882	3,396,334
1883	5,207,553
1884	3,693,325
1885	3,368,549
1886-1892	23,652,315
1893	6,092,377
1894	7,063,442
1895	6,984,273
1896	5,813,387
1897	7,242,004
1898	8,686,681
1899	9,040,871
1900	5,765,559
1901	6,989,668
1902	8,110,898
1903	8,357,661
1904	6,800,235
1905	7,675,088
1906-1908	21,000,000

Estimated Total: 178,204,017 lbs. or 89,102 short tons

SOURCE: U.S. Bureau of Mines, Mineral Resources of the U.S. (1883 & 1884, 1885, 1901, 1905).

TABLE 5-1 (cont'd)

Year	Arsenic trioxide (short tons)	Sulfide of arsenic & orpiment (short tons)	Paris green & London purple (pounds)
1909	445	3,591	183,765
1910	1,348	3,791	181,363
1911	1,921	2,175	126,191
1912	3,103	3,053	162,272
1913	1,519	3,182	99,692
1914	1,594	2,034	15,476
1915	1,400	1,783	21,056
1916	1,071	1,092	23,461
1917	1,178	2,777	48
1918	1,847	4,842	--
TOTALS	15,426	28,320	813,324 lbs or 407 short tons

SOURCE: U.S. Bureau of Mines, Mineral Resources of the U.S. (1918).

TABLE 5-2

Lists of Manufacturers and Dealers, 1934

The following lists of manufacturers and dealers have been compiled from various trade directories but are not necessarily complete.

White arsenic

Anaconda Copper Mining Co., Anaconda, Mont.
American Smelting & Refining Co., 120 Broadway, New York, N.Y.
American Metal Co., 61 Broadway, New York, N.Y.
Harshaw Chemical Co., Cleveland, Ohio.
Mallinckrodt Chemical Works, St. Louis, Mo.
H. J. Baker & Bro., 271 Madison Avenue, New York, N.Y.
Charles Cooper & Co., 4 Mulberry Street, New York, N.Y.
Innis, Speiden & Co., 117 Liberty Street, New York, N.Y.
Howard W. Ambruster, 261 Broadway, New York, N.Y.
Bartlett Chemicals, Inc., American Bank Building, New Orleans, La.
Adolph Hirsh & Son, 25 Spruce Street, New York, N.Y.
Mitsui & Co., Ltd., Empire State Building, New York, N.Y.
Philipp Bros., Inc., 233 Broadway, New York, N.Y.
Roessler & Hassacher Chemical Co., Empire State Building, New York, N.Y.
U.S. Smelting, Refining & Mining Co., 57 William St., New York, N.Y.
Grasselli Chemical Co., Inc., Cleveland, Ohio.
John C. Wiarda & Co., Div. of Kalbfleisch Corporation, 200 Fifth Avenue, New York, N.Y.
Deloro Smelting & Refining Co., Ltd., Deloro, Ontario, Canada.
Pfaltz & Bauer, 301 Pearl Street, New York, N.Y.
Sterling Products Co., Easton, Pa.

Lead arsenate

W. A. Allen, Pittstown, N.J.
Howard W. Ambruster, 261 Broadway, New York, N.Y.
Joe Barlow, distributor, Crowdus and Taylor Streets, Dallas, Tex.
Bowker Chemical Co., 419 Fourth Avenue, New York, N.Y.
California Rex Spray Co., Benicia, Calif.
California Spray Chemical Co., 15 Shattuck Square, Berkeley, Calif.
Dow Chemical Co., Midland, Mich.
General Chemical Co., 40 Rector Street, New York, N.Y.
Grasselli Chemical Co., Empire State Building, New York, N.Y.
Adolph Hirsh & Son, 25 Spruce Street, New York, N.Y.

SOURCE: Tyler, P. M., and A. V. Petar, U.S. Department of Interior Economic Paper 17 (U.S. Government Printing Office, 1934), pp. 32-33.

TABLE 5-2 (cont'd)

Interstate Chemical Co., 667 Garfield Avenue, Jersey City, N.J.
Latimer Goodwin Chemical Co., Grand Junction, Colo.
Lucas Kil-Tone Co., Vineland, N.J.
Mechling Bros., Chemical Co., Line Street and Copper Creek, Camden, N.J.
National Chemical Co. of California, 310 Sansome Street, San Francisco, Calif.
Sanocide Spray Co., Fennville, Mich.
Sherwin-Williams Co., 601 Canal Road, N.W., Cleveland, Ohio.
Standard Chemical Works, Inc., 31 North Sixth Street, Reading, Pa.
Toledo Rex Spray Co., Toledo, Ohio.
J. W. Woolfolk Co., Fort Valley, Ga.
Mallinckrodt Chemical Works, St. Louis, Mo.
American Agricultural Chemical Co., New York, N.Y.
Chipman Chemical Engineering Co., Inc., Bound Brook, N.J.
Miller Products Co., Portland, Oreg.
Niagara Sprayer & Chemical Co., Middleport, N.Y.
Braun-Knecht-Helmann Co., Ltd., San Francisco, Calif.

Red arsenic

Howard W. Ambruster, 261 Broadway, New York, N.Y.
Ore and Chemical Corp., 40 Rector Street, New York, N.Y.
Roessler & Hasslacher Chemical Co., Empire State Bldg., New York, N.Y.
Wiarda & Hall Acid Works, Inc., 518 Gardner Avenue, Brooklyn, N.Y.
J. T. Baker Chemical Co., Phillipsburg, N.J.
A. Daigger & Co., 159 West Kinzie Street, Chicago, Ill.
Harshaw Chemical Co., Cleveland, Ohio.
Mallinckrodt Chemical Works, St. Louis, Mo.
Braun-Knecht-Helmann Co., Ltd., San Francisco, Calif.
Innis Speiden & Co., Liberty Street, New York, N.Y.

Calcium arsenate

Niagara Sprayer & Chemical Co., Middleport, N.Y.
J. T. Baker Chemical Co., Phillipsburg, N.J.
Grasselli Chemical Co., 629 Euclid Avenue, Cleveland, Ohio.
General Chemical Co., 40 Rector Street, New York, N.Y.
Bowker Chemical Co., Fourth Avenue and Twenty-ninth Street, New York, N.Y.
Miller Products Co., Portland, Oreg.
Dow Chemical Co., Midland, Mich.
American Agricultural Chemical Co., New York, N.Y.
Chipman Chemical Engineering Co., Bound Brook, N.J.
Braun-Knecht-Helmann Co., San Francisco, Calif.
The Brown Co., Berlin, N.H.
W. R. Crum & Co., Savannah, Ga.
Merrimac Chemical Co., 148 State Street, Boston, Mass.

TABLE 5-2 (cont'd)

Commercial Chemical Co. of Tennessee, Memphis, Tenn.
Sherwin-Williams Co., 601 Canal Road, N.W., Cleveland, Ohio.
Interstate Chemical Manufacturing Co., Jersey City, N.J.
Lucas Kil-Tone Co., Vineland, N.J.
John Lucas & Co., 322 Race Street, Philadelphia, Pa.
Elmer and Amend, New York, N.Y.
G. S. Alexander Co., Inc., Charleston, S.C.
W. A. Allen, Pittstown, N.J.
Howard W. Ambruster, 261 Broadway, New York, N.Y.
Joe Barlow, Distributor, Crowdus and Taylor Streets, Dallas, Tex.
Bartlett Chemicals, Inc., American Bank Bldg., New Orleans, La.
Adolph Hirsh & Son, 25 Spruce Street, New York, N.Y.
McCandless Laboratory, Rhodes Bldg., Atlanta, Ga.
National Chemical Co. of California, 310 Sansome Street, San Francisco, Calif.
Sanocide Spray Co., Fennville, Mich.
Toledo Rex Spray Co., Toledo, Ohio.
J. W. Woolfolk Co., Fort Valley, Ga.

Arsenic acid

Grasselli Chemical Co., 629 Euclid Avenue, Cleveland, Ohio.
The Glidden Co., 11001 Madison Avenue, Cleveland, Ohio.
Dow Chemical Co., Midland, Mich.
Commercial Chemical Co. of Tennessee, Memphis, Tenn.
Corona Chemical Co., 217 Lake Street, Milwaukee, Wisc.
Sherwin-Williams Co., 601 Canal Road, N.W., Cleveland, Ohio.
Stratford Co., Morganville, N.J.

water is poorly documented and/or understood at present. Dredging of water bodies may also re-expose sedimentary arsenic deposits; such dredging is likely to be extensive in the near future in connection with several public programs--for example, the repair of unsafe dams or the rehabilitation of old dams to produce hydroelectricity, the building or enlarging of river and ocean ports to handle the export of coal, and the building of docks or bulkheads because of the continuing migration of the population into rural areas and the margins of water bodies.

5.1.2 The Sources of Arsenic

The ancient Greeks knew of arsenic sulfides (realgar and orpiment) as medicines and dyes but made no references to their potential as poisons.[1] After the thirteenth century, however, when pure arsenic was first described by Albertus Magnus, its toxicity fascinated alchemists, murderers, and story-tellers alike.[2] The fascination has endured; one example is the title of a popular play and movie, Arsenic and Old Lace, despite the fact that the murders that are the basis of the plot were perpetrated using cyanide, which kills more swiftly than arsenic.

In the eighteenth century, arsenic was identified as an element. It occurs in small amounts throughout the earth's crust, usually associated with nonferrous metal ores--copper, lead, zinc, gold, and silver.[3] It is the twentieth most abundant element in the earth's crust, the fourteenth most abundant element in sea water, and the twelfth most abundant element in the human body.[4]

During the 1800's, most of the arsenic used in the United States was imported from England, where it was obtained as a byproduct of copper and tin mining in Cornwall and Devon.[5] In the United States, some arsenic was obtained as a byproduct of copper smelting. It collected in the flue dust and at the beginning of the 1900's, it was generally thrown into land dumps or streams.[6] The opening of mines especially for arsenic ores began in 1901 in the state of Washington.[7] Arsenic was never mined or refined in the eastern United States, although that was where the market for commercial arsenic was located. Prices for arsenic from England and the western United States remained competitive throughout the early twentieth century.[8]

In 1923, because of a drop in supplies, the U.S. Geological Survey (USGS) made a study of the domestic sources of arsenic, since its refining was by then profitable. The results were:

Source	Percent of Supply
Regular ore charges of smelters	50
Arsenical slag or speiss dumps at Eureka, Nevada, and arsenical ores processed by smelters	40
Ore roasted for arsenic in Montana and Nevada plants, then shipped elsewhere for gold and silver extraction	10

By the time of the USGS report in 1923, deposits of arsenic were being mined in Montana, Nevada, and Utah with promising further development in Colorado, South Dakota, Washington, and California.[9]

Arsenic also occurs naturally with and in coal, from which it is released by combustion and in coking processes, and in oil shale.[10] It could thus become an important environmental concern in future energy development. Humans are directly exposed to arsenic in some other natural conditions--for example, when a water system includes hot springs that produce arsenic and are also a source of drinking water. Arsenic is also found in seafood, especially shellfish such as shrimp, lobster, and clams, which absorb arsenic from sea water.[11]

5.1.3 Effects

Arsenic is capable of inflicting damage to a number of systems in the human body, and to other living organisms. In solid form it is tasteless, but high concentrations of arsine gas (AsH_3) give off the odor of garlic, which can be detected on the breath of one suffering from arsenic poisoning.[12] Arsenic can enter the body through the skin or in respiration, but most commonly it is ingested. Table 5-3 shows the body systems affected by arsenic and the results.

TABLE 5-3
Effects of Arsenic Poisoning

System	Symptoms
Gastro-intestinal	Metallic taste, garlic odor, dryness in mouth and throat, burning pain in stomach, profuse diarrhea
Dermatologic	Skin eruption and ulceration, perforation of nasal septum
Musculoskeletal	Muscular cramps
Circulatory	Rapid feeble pulse, cold clammy extremities, sighing respiration, cyanosis
Neurologic	Frontal headache, vertigo, depression, stupor, convulsions

SOURCE: U.S. Department of Health, Education, and Welfare, Health Effects of Occupational Lead and Arsenic Exposure (U.S. Government Printing Office, February 1976), p. 242.

There is evidence that arsenic is related to arteriosclerosis and chronic liver disease.[13] It is toxic to the heart and kidneys and recently also has been found to be a subtle carcinogen, affecting the lungs, skin, and possibly the liver.[14]

When arsenic is taken in by the body, some of it will remain in the hair and fingernails, providing a test for the presence of arsenic. It was discovered recently that Napoleon's hair held traces of arsenic, which could be interpreted to mean either that Napoleon had been poisoned--perhaps by the British on St. Helena, where he was exiled or--more likely in light of the nineteenth-century pharmacopoeia, that he had been heavily treated with arsenical medicines.[15]

A doctor who compiled and published a number of arsenic poisoning case histories included in the Report of the Board of Health of Massachusetts, 1883, pointed out that because the effects of gradual arsenic poisoning are delayed and subtle, it is difficult to connect the symptoms with the source of poisoning. The doctor noted that he was able to see symptoms of poisoning in members of his own family, and thus to track down the source, only because he was able to observe his own family over the course of many hours.[16]

Common symptoms of mild cases of arsenic poisoning are nausea, soreness, irritation of the nose and eyes, and lack of energy.[17] It is likely that many people in the nineteenth century suffered from arsenic poisoning without having it diagnosed, and the same may well be true today.

5.1.4 Enduring Problems Related to Arsenic

Twentieth-century legacies from nineteenth-century use of arsenic may include: (a) effects of arsenic pesticides, (b) latent storage of arsenic in consumer products, (c) arsenic residues in old buildings, and (d) waste dumps and mine tailings.

5.1.4.1 Arsenic as a pesticide. The history of arsenic is not comparable to the all too common situation today of a freely used substance whose toxic qualities only become apparent years later. In the nineteenth century arsenic was considered a deadly poison and was handled with care and treated with suspicion. However, its persistence was not fully appreciated, and disposal procedures were unsophisticated and geared toward the immediate rather than the long range fate of toxics.

Appreciation of the poisonous characteristics of arsenic led to its most important commercial application--as a pesticide. In the mid-1800's the urban population of the United States was increasing much more rapidly than the rural population (see Table 5-4); together with breakthroughs in transportation technology (the railroad in the 1840's and steam shipping in the 1860's), this increase encouraged commercial farming.[18] However, agriculture was bedeviled by pests, which were inadequately controlled by pesticides of the era, "hellbore, quassia, lime, and tobacco."[19] In the summer of 1867, the potato beetle threat was effectively wiped out by the use of a new arsenical insecticide, Paris Green, a copper acetoarsenite (approximately ${}_3Cu(AsO_2)_2{}^{\sim}Cu(C_2H_3O_2)_2$).[20] Paris Green was widely used during the last third of the century along with lead arsenate (approximately $PbHAsO_4$), which was developed in 1892 to fight the gypsy moth, and calcium arsenate, which was developed to counter the cotton boll weevil.[21] Lead arsenate was the leading pesticide until World War II and the development of DDT.

From the beginning, there was concern that spraying with arsenic would poison crops and livestock. A study published in 1875 (8 years after the potato beetle

TABLE 5-4

Nineteenth-Century U.S. Population--Rural/Urban (in thousands)

Date	Urban	Rural	%Urban	%Urban Increase	%Rural Increase
1790	202	3,728	5		
1800	322	4,986	6	59	34
1810	525	6,714	7	63	35
1820	693	8,945	7	33	33
1830	1,127	11,739	9	63	31
1840	1,846	15,224	11	64	30
1850	3,544	19,648	15	91	29
1860	6,217	25,227	20	75	28
1870	9,902	28,656	26	59	13
1880	14,130	36,026	28	43	26
1890	22,106	40,841	35	56	13
1900	30,160	45,835	40	36	12
1910	41,999	49,973	46	39	9
1920	54,158	51,563	51	29	3

SOURCE: U.S. Bureau of Census, Historical Abstracts, .

episode) concluded--on scientific grounds that were dubious even in 1875--that arsenic pesticides presented no problem.[22] Another, somewhat later study said that livestock was safe but that pesticides could affect beekeeping.[23] The pressure to use pesticides, and the questionable but reassuring studies on their effects, assured their continued use until World War II. They were partially prohibited in 1968, after their use had already greatly declined.[24]

In the past 20 years, a number of studies have attempted to ascertain the environmental effects of the long use of arsenic pesticides. Some conclusions were that "very high arsenic levels in the soil have accumulated in areas of earlier high applications of arsenic pesticides."[25] Arsenic buildup in fields in which it was used to control the boll weevil, for example, continued up to 60 years.

It is not clear, however, that the presence of high amounts of arsenic in the soil has been damaging to human health. According to one study, "Past use of arsenicals has not resulted in serious problems with human or animal poisoning, but severely reduced plant growth due to arsenic phytotoxicity has been observed, especially on former orchards and cotton fields."[26]

High concentrations of arsenic persist several years after the use of arsenic as a pesticide is discontinued. How long is still uncertain. Arsenic can be dispersed from surface soil in a number of ways. It is subject to both water and wind erosion. It leaches through the soil, reducing surface soil concentrations. Whether it then seriously contaminates groundwater has been the subject of at least 11 major studies, all of which concluded that the possibilities of such contamination appeared insignificant. "All of the conditions which favor leaching . . .were tested; but leaching below the 90 cm. depth of soil was not observed," one study concluded.[27]

Apple orchards in the northwestern United States especially are said to show high concentration of arsenic at the dripline under the trees. When the field is turned over to grain, the outline of the trees is visible for a number of years until it gradually disappears.

In general, the arsenic leaches down to the subsoil where it is fixed on iron, etc., and remains indefinitely. Levels are too low to present hazards, however, in the case of excavation. In Florida, where arsenicals are used as a growth regulator on grapefruits, the arsenic leaches through the sandy soil, but despite tests, no significant trace has been found in the groundwater.[28] However, this problem cannot be entirely dismissed, because the health effects of arsenic are significant and the final repository of the arsenic contained in pesticides is still uncertain. As discussed in Section 5.4 of this report, much of it may have found its way to sediments in rivers, reservoirs, lakes, and bays.

Regulations were promulgated in 1968 providing that crops may not be grown in soil containing arsenic. According to interviews with experts at the U.S. Department of Agriculture (USDA), shortly before 1968 the law was changed to make it the responsibility of arsenical pesticide manufacturers to show that the arsenic tolerance they were requesting was not harmful. Most manufacturers were unwilling to go to the trouble of researching such information, preferring to switch to nonarsenical ingredients. Therefore, in 1968, the USDA issued Pesticide Regulation (PR) 68-6 cancelling most arsenical pesticide products. In 1969, PR 69-4 cancelled additional lead arsenates and in 1970, PR 70-4 cancelled arsenical pesticides used on potatoes. In 1971, pesticide regulation authority was transferred to EPA.[29]

There have been a number of attempts to perfect ways of removing arsenic from soil. Forcing it to leach through, plowing arsenic-contaminated soil below root depth, or adding substances to adsorb or desorb it have all been tried.[30] Elemental arsenic will disappear through sublimation, but the arsenic used in commerce is "white arsenic" or arsenic trioxide (As_2O_3), which will remain in particle form indefinitely.[31] At present there is no completely satisfactory way of assuring its full removal from agricultural soil.

5.1.4.2 Arsenic in Pigments and other Consumer Uses. The second most common use of arsenic in the nineteenth century was as a source of pigments, primarily for the color green. In 1872, for example, there was "widespread use of Paris and Scheele (copper arsenate, $CuHAsO_3$) greens as pigments in coloring artificial flowers, articles of dress, pastry ornaments, toys, house paints, glazed papers, and paper hangings."[32] A study of arsenic poisoning in 1883 referred to "the green arsenious lampshades, universally employed."[33]

Arsenic was also used in the manufacture of fuchsin (bluish-red pigments), magenta, safranin (red), some anilin maroons and browns, and several mordants used to fix red and purple colors.[34] Thus, consumers could not know whether an object was arsenic-free merely by checking its color, and in general the public associated arsenic only with green pigments.

Arsenic pigments were widely used in playing cards, stuffed animals, flannel, stockings, carpeting, and furs--especially rugs and robes of bearskin (very popular in the late 1800's) in which it was used both as a dye and to discourage bugs.[35] In a few cases, such as pastry ornaments, arsenic was used in foods. It was considered most dangerous in candles and in wallpaper because of their extensive use.[36]

The public became concerned about arsenic-laden wallpaper in the 1870's. The 1875 Encyclopaedia Britannica article on arsenic discussed this concern and stated (inaccurately) that it was possible to get sick from particles of arsenic taken in through the skin in cleaning wallpaper but that there were no dangers from breathing in dust or gas (sublimated arsenic) given off by the paper.[37] There continued to be public concern about arsenic-laden wallpaper until the end of the century when some states passed regulations against its sale.[38]

Arsenic was also added to lead in making bullets because it made the shot ball rounder.[39] It was added to glass to counteract the coloring effect of metallic oxides and to give brilliancy.[40] It was used in tanning as a depilatory and, as a preservative, both in leather making and in taxidermy.[41] Sodium arsenite was used in making soaps for scrubbing skins and hides,[42] and arsenic also was used in fireworks.[43]

Arsenic was widely used in medicines (for which it is still used). A popular health tonic of the 1800's, also prescribed for leukemia, was Fowler's Solution; it contained arsenic, as did other popular tonics.[44] Arsenic also was used in tablets prescribed "to kill the nerves of teeth."[45] Mapharsen or neoarsphenamine was used until recently against syphilis and gonorrhea (and may in fact be resubmitted for approval by the Food and Drug Administration in the future).[46] Triparsimide was developed in 1929 and remains the only medicine for certain types of sleeping sickness.[47] Medicines from the nineteenth century are not likely to be still in circulation, but it is possible that buildings and building sites where such pharmaceuticals were manufactured may contain hidden residues of arsenic.

5.1.4.3 Arsenic Residues in Buildings and Equipment. In industrial processes arsenic is now considered a potent threat to the safety and health of workers, especially in the following occupations (most of which were also nineteenth-century occupations):

> Nonferrous metal ore miners and smelter workers (copper, zinc, nickel); makers of alloys, pigments, paper, paints, inks, glass, ceramics, preservatives of woods, pelts, etc.; herbicides, pesticides, algicides, rodenticides, cattle and sheep dips, war gases, hair lotions, animal feed additives, pharmaceutical preparations, and vineyard workers.[48]

Also at risk are (and were):

> Persons living and working in the fume and dust zone of such plants and in areas sprayed or dusted with pesticides; eating contaminated food and drink; and inhaling air heavily polluted with coal smoke, treated internally with arsenicals.[49]

Preserved hazards in the form of arsenic residues in old factories, equipment, and onsite waste dumps associated with such activities could re-emerge during the clearing and excavation of sites, the destruction of buildings, or their rehabilitation or conversion to other uses. It is increasingly common, for example, for old factories to be converted to use as chic shopping malls or restaurants. In New York City, industrial lofts that may have once produced clothing, carpets, furs, artificial flowers, and other consumer products using arsenic are now sought after as residential flats or artist's studios. Arsenic embedded in walls, floors, and structural elements could be hazardous to workmen dismantling or remodeling such buildings, or to their new residents.

The potential for hazardous residues in such buildings may be large because relatively few precautions against contamination were enforced in the nineteenth century. In 1912 a description was published of unsafe working conditions discovered in a study of four Paris Green insecticide plants.[50] Although it was well known that Paris Green powder was highly toxic, two of the factories provided little protection for workers and enforced few safety rules: workers had "almost no washing facilities, no place to eat lunch, eating in the workroom (was) permitted, primitive sanitary conditions, lack of instructions or even lack of recognition of danger on the part of the employers. . . ."[51]

5.1.4.4 Waste Dumps and Mine Tailings. In the nineteenth century, manufacturing wastes were typically piled or buried on site or dumped into nearby rivers, lakes, or canals. Such wastes may be encountered during excavation or conversion of old factory sites, and their toxic contents may not be recognized. Waste piles can sit undisturbed and unrecognized for many decades. A recent example has come to light in North Woburn, Massachusetts, where over one hundred years ago Merrimack Chemical Company began making chemicals for the textile industry.[52] Merrimack expanded to become one of the largest producers of arsenic-based pesticides.

> In the summer of 1979, officials learned that there was an open pit, a dry lagoon, covering about an acre of land in which arsenic was piled in caked white powder several feet thick. So concentrated were the arsenic, lead, and other chemicals that a mere 45 pounds of the soil would (contain) enough to administer a lethal dosage to 100 adults. . . . To compound the problem the arsenic has been scattered widely by winds and rain and has contaminated a river watershed known as the Aberjona, which courses through Winchester on its way to the Atlantic Ocean. Nearby Mystic Lake may also be endangered.[53]

On February 21, 1981, the Boston Globe reported that the National Center for Disease Control was examining infants in Hudson, New Hampshire, who had been exposed to high levels of arsenic found in at least 63 wells in the community. Nine other New Hampshire communities, and a few in Massachusetts, were also found to have high concentrations of arsenic (in concentrations of over .05 milligrams per liter). According to the Globe, the EPA had launched an investigation to "determine whether the arsenic is a natural component of the water or represents manmade pollution." Although the newspaper did not mention it, and EPA may not yet have realized it, it is quite possible that the arsenic in the New England wells is a residue from nineteenth century industries.

Arsenic ore, as already discussed, is usually found in conjunction with other nonferrous metals and is frequently produced as a byproduct of copper, gold, and silver mining. From mine tailings (waste piles) arsenic may leach into groundwater. The extent of this problem has not been thoroughly assessed on a national scale. In a study of Whitewood Creek, Belle Fourche River, and part of the Cheyenne River (all in South Dakota), high arsenic levels were found in groundwater in the surrounding area as a result of leaching of mine tailings, direct recharge, and bacterial action related to one hundred years of gold mining.[54] There is thus a reasonable suspicion that similar contamination of water resources may be associated with other mining lands in the West.

5.1.5 A Recent Example

The following example concerns arsenic from a slightly later period, but it is useful because it indicates the way in which arsenic can be inadvertently hidden or stored and the measures that may be needed to deal with its discovery.

In 1974, health inspectors in the Alexandria, Virginia, Health Department were making a routine patrol of the Potomac River shore just outside of Washington, D.C., and they noticed a yellowish discoloration in the water. Tracing the effluent back through a storm sewer outlet, they discovered workers at a local industry cleaning out a railroad tank car with a water hose. The contents of the tank car were industrial chemicals.

The hosing of tank cars, with the water vented into the river, was stopped. But the question had been raised as to what previous contamination may have occurred.[55]

It was soon learned that the company had been manufacturing pesticides since the early 1930's, and that until 1966 the pesticides contained arsenic.[56] Some 305,000 cubic feet of soil were found to be contaminated with arsenic trioxide (AS_2O_3) as a result of accidental spills and the flushing out of railroad cars over the years.[57] One hundred twenty milligrams of this form of arsenic constitutes a lethal dose; it was used at that time as a herbicide to spray weeds growing along railroad tracks.[58] Arsenic trioxide is water soluble and can leach through soil into groundwater; what had been left in the soil was insoluble and indestructible.

The company was ordered to have the entire area tested for arsenic. "On about a 5-acre tract arsenic readings ranged from 25 ppm to around 29,000 ppm."[59] There were also tests for arsenic in the air, but none was found.[60]

Most of the soil contamination was within the first 15 inches of the surface and mainly on the company's property. Because there was an underlying layer of impermeable clay, the groundwater did not show endangering quantities of arsenic.[61] About 2.5 pounds of arsenic were entering the river per year, which is not considered a significant contaminant.[62] There are no other streams in the area, so the sediment of a small section of the Potomac River bed was the only significant waterway affected.[63]

Because the arsenic was indestructible, no one would accept responsibility for digging up and disposing of the arsenic-contaminated soil, even if this were possible. The solution was to neutralize the soil by covering it with at least 18 inches of iron-rich clay. Then, if arsenic migrated up into the clay, it would be "fixed" by the iron.[64] In order to keep the clay cap from eroding, an additional six inches of gravel or four inches of top soil with seeding or sod was placed on top, and three storm drains were raised to the new height of the surface.[65]

The land was later sold and the new owner was given a permit to build offices and a restaurant on the site. Adjacent to the property, townhouses were added.[66] All procedures for the onsite construction work had to be coordinated with the Health Department to ensure safety.[67] Construction workers were trained in safety procedures and wore protective clothing, including washable rubber boots, coveralls, impervious gloves, hair covering, respirators and filters, and eye protection.[68] On leaving the contaminated area and before smoking or eating, they had to remove protective clothing and wash; before leaving the site they had to shower and shampoo.[69]

Excavation was minimized. Basements were kept as small as possible and utility lines placed above the surface where practicable. When water and sewer lines had to be put below the surface, trenches were built and sided with 18 inches of iron-rich clay.[70] All soil had to remain onsite, as well as all washings from trucks, showers, and other equipment.[71] In addition, arsenic was discovered in some of the structures onsite, even on top of rafters. These were cleaned if they were to remain.[72]

Traces of mercury were also found in the soil, but it was determined that this was the product of coal combustion at a coal-burning powerplant two thirds of a mile upwind.[73]

No traces of contamination in the bodies of workers and nearby residents were found, despite extensive testing,[74] and no detrimental impacts of the arsenic contamination could be demonstrated in this case. However, once the contamination--which had occurred from 10 to 40 years earlier--was discovered, sound public policy had to require that the potential hazard be eliminated. Although no figures are available to us, the costs in money and time of the corrective actions--to industry and to the public--were undoubtedly large.

5.1.6 Conclusions and Recommendations

The extensive use of arsenic in the nineteenth century may well have left significant environmental, health, and safety problems for the twentieth and twenty-first centuries. The volume of arsenic left behind from nineteenth-century applications is no doubt small in comparison with the toxic substances produced by the "chemical revolution" in American industry following World War II. However, it should not therefore be discounted.

There still may be heavy concentrations of arsenic wastes in localities where:

- Arsenic was mined or produced as a byproduct of mining and smelting other ores
- Small and large urban areas had concentrations of industry during the nineteenth century
- Agricultural pesticides containing arsenic were applied over many decades
- Dredge materials from waterways or canals are deposited, if there were nineteenth-century industrial sites near the waterways.

The extent of additional general public risk or ecological problems from arsenic contaminated soil and groundwater has been studied, but evidence is so far inconclusive. Special groups who may be at particular risk include those who dismantle or renovate and convert old buildings; and collectors, restorers, or users of a variety of nineteenth-century artifacts.

Action options to be considered by EPA are:

1. Conduct further research on the persistence, transport, and effects of arsenic contaminants in agricultural soils and groundwater;
2. Advise and assist states and localities in reviewing their mining and industrial history; in identifying sites where arsenic was produced,

processed, or utilized; and in assessing the residual hazards at such sites. (This might be done in conjunction with the National Parks Services Historic American Engineering Review.)

3. In collaboration with the Army Corps of Engineers, immediately conduct studies to assess the possible occurrence and volume of arsenic (and other persistent toxic substances) in sediments dredged from water bodies in the course of dam building or rehabilitation, port construction, and other activities performed or permitted by the Corps.

4. Initiate research to assess the health and safety effects of arsenic embodied in nineteenth-century artifacts; undertake a public education program to alert restorers and collectors, museum staff, hobbyists, antique dealers, and the medical profession to potential dangers related to arsenic and to make them familiar with symptoms of arsenic-related health effects.

5.2 OLD KING COAL

5.2.1 Summary

The coal industry was in its heyday between 1870 and 1920, when coal was the dominant fuel for America's industry. Coal also heated America's homes, and for a few decades coal gas illuminated its streets, public buildings, and residences. Coal-based chemistry also provided many widely used industrial materials and consumer products.

Enduring environmental problems left over from nineteenth century mining are well recognized, widespread, severe, and, to a large extent, not yet solved. The problems associated with coal combustion in the past have in part gone with those who suffered from them, and those problems that remain--such as damaged art work and deteriorated building facades and bridges--can hardly be distinguished from the results of twentieth-century contaminants. Coal-based products are now known to contain carcinogens, and here the residuals from the last century are less studied and less well recognized. Unless the lessons of the past are appreciated, these problems may well recur if the national policy of encouraging coal use is successful.

Although long used for heating, coal use and the coal industry expanded greatly with the invention of the steam engine and the Industrial Revolution. The life pattern of many similar major industries since 1800 is one of continuing technological innovation--increasing mechanization, one or more fuel conversions (wood, coal, oil, nuclear), and very recently, automation and computerization--an evolutionary but dramatic change from labor-intensive, rudimentarily equipped workplaces to modern facilities in which fewer and more highly skilled workers supervise sophisticated machinery. The coal industry, however, does not exhibit this pattern of steady modernization, and for that reason the techniques used in the nineteenth century may have especially strong impacts on the twentieth century. Some significant problems have never been solved; some mistakes made in the past may be allowed to recur in the future. This brief case study will survey enduring environmental problems that may be traceable to the past, beginning with the mining of coal and continuing through coal preparation and combustion, and coal-derived products.

5.2.2 Coal Mining

Coal mining in the United States increased rapidly from 1870 to 1920. In 1902, there were at least 5,985 coal mines located in 28 states (Table 5-5). During this time the technology of coal mining advanced. But after 5 decades of rapid growth, demand for coal peaked in 1920 and then ceased to grow and even declined for 4 decades. During this time there was little innovation in coal mining technology.[1]

The rapid growth in consumption of oil and natural gas was, of course, largely to blame for this stagnation. Coal had been the main source of energy for the last third of the nineteenth-century and the first decades of the twentieth; but once they could be produced in suitable commercial quantities, oil and gas rapidly took over the coal market largely because they are much cleaner and easier to transport and handle.

Now that the possibilities of coal as a major fuel source are receiving concentrated attention, there may be a new wave of innovation and modernization in coal mining. It also becomes important to recognize and rectify, where possible, past errors. The Surface Mining Control and Reclamation Act (SMCRA), passed in 1977, attempts to address all known aspects of environmental hazard caused by surface mining and also to deal with the problems caused by underground mining. The Office of Surface Mining (OSM) within the Department of Interior was created by SMCRA to oversee such regulations. SMCRA is aimed primarily at surface mining, because since the 1950's it has been the major form of mining and it is acknowledged to be an environmentally destructive process. However, SMCRA also makes OSM responsible for problems of abandoned (or "orphan") underground mines.[2]

One of the largest obstacles to solving the problems of inactive or abandoned coal mine lands has been the apportionment of responsibility for cleanup. In many cases the mining companies have gone out of existence, and in other cases it may not be possible to ascertain what company was responsible. If no private responsibility can be assigned, the lands are put under the jurisdiction of OSM. If, however, a company at any time does want to reclaim and reuse the land, it becomes responsible for its complete reclamation.[3]

In order to assess the extent of the problems of abandoned mine lands, the OSM began an inventory of those lands in 1979.[4] The first phase of the inventory was a literature study of the problems, which is completed. The second phase has now begun. As a first estimate there appear to be at least 30,000 problem areas. Field workers are consulting local officials and professionals in these areas to discover what is known about these problems. They will then be dealt with according to priority. First priority problems are those that involve safety and health. Second are environmental problems, and last, solely aesthetic problems. Funding for the inventory amounts to $200 million a year for 15 years or a total of $3 billion by 1992. Estimated costs for a complete cleanup are in the range of $30 billion.[5]

TABLE 5-5

Mines and Quarries in 1902

Bituminous Coal

State	Number of Mines
Alabama	145
Arkansas	53
California	10
Colorado	126
Georgia	3
Idaho	5
Illinois	875
Indian Territory (Oklahoma)	58
Indiana	339
Iowa	326
Kansas	175
Kentucky	523
Maryland	44
Michigan	31
Missouri	384
Montana	37
New Mexico	30
North Dakota	47
Ohio	648
Oregon	9
Pennsylvania	1,023
Tennessee	84
Texas	26
Utah	39
Virginia	26
Washington	27
West Virginia	522
Wyoming	36
Anthracite Coal	
Pennsylvania	334

SOURCE: U.S. Dept. of Commerce and Labor, Mines and Quarries 1902 (U.S. Government Printing Office, 1905).

5.2.2.1 Acid mine drainage. It is very difficult to keep water from entering underground mines, especially the older ones, which have been subjected to subsidence and weathering.

> Above the coal seams there are frequently aquifers or layers of water-bearing rock. During or after the deep-mining procedure, the roof of the mine may buckle, causing. . .subsidence; as a result. . ., the aquifers may be fractured, releasing water into the mine cavity. Rainfall may also percolate from the surface down into the mine through these subsidence fissures. Aquifers are also frequently found beneath the coal seams. After deep mining has been completed, the floor of the mine may heave up, breaking these underlying rock layers and permitting water to rise into the mine. Strip mining on the surface may funnel water into the underground workings of the same coal seams.[6]

When water enters a coal mine, it completes the reaction of coal plus air, and acid water results. Oxygen combines with the iron sulfide minerals in the coal, forming iron compounds and sulfuric acid, which is water soluble;[7] the acid water then seeps back into groundwater and streams.

It has been estimated that "10,000 miles of streams and rivers, principally in Appalachia, have been degraded by acid drainage."[8] According to one study, the percentage of drainage that comes from inactive underground mines is 53 percent or 1,712,000 pounds a day acidity.[9]

This acidic drainage produces a number of environmental impacts. First, it makes the water unsuitable for domestic and industrial use.[10] Municipalities must neutralize the water and accept the increased hardness. Industries must use corrosion resistant materials, treat the water, or bear the loss if no alternate water source can be found.[11]

Second, the acid is toxic to aquatic life.[12] This problem is compounded by the fact that the lowered pH water will dissolve heavy metal compounds such as aluminum, manganese, zinc, and nickel.[13] The last two are also known carcinogens and are "often present in substantial quantities."[14]

These metals become part of the sediment through adsorption. "The largest reservoir of trace contaminants resides in the bottom sediment and is available to the rest of the ecosystem according to a complex web of factors."[15] Furthermore, iron salts are precipitated onto the bottom, effectively smothering bottom-dwelling organisms.[16]

Increased siltation occurs as the water in the mines erodes the mineral particles and carries them downstream.[17] On a national scale, mining is a small source of sediment, but in a local area, it can go on producing sediment for years.[18]

Because of the same chemical reaction, acidic drainage also is produced in water runoff from a coal refuse pile. The amount of water, however, is much less.[19]

In general, techniques do exist that can stop acid runoff from refuse piles, but methods of stopping it from underground mines are not consistently successful. Some of these methods are: 1) sealing the mine to prevent air infiltration; 2) filling the mine with water; 3) preventing water infiltration by grading, sealing, aquifer control, etc.; 4) backfilling the mine; and 5) removing mine pillars and allowing the mine to collapse.[20] None of these techniques is highly successful, particularly in the older mines.[21]

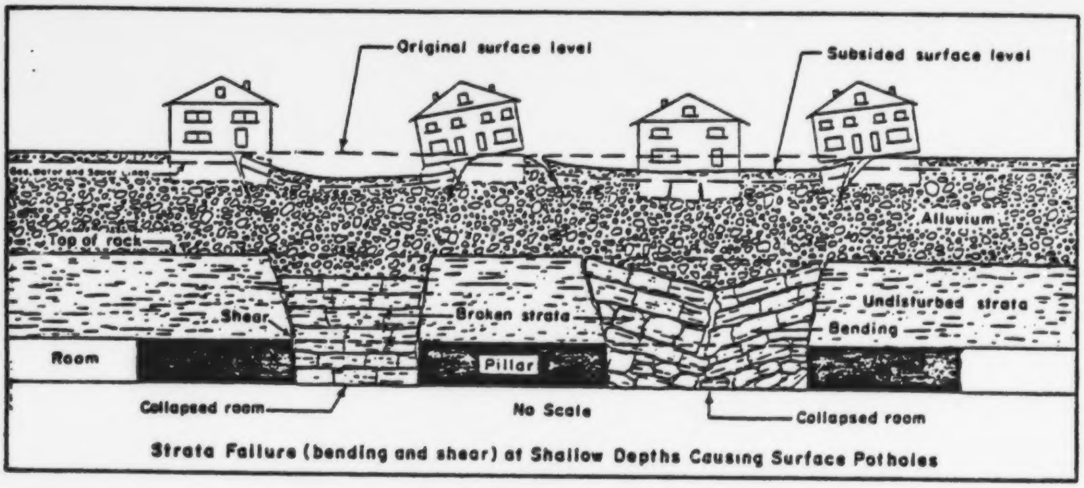
Eventually, because of the provisions of SMCRA, acid drainage may decline since underground mining will soon be going deep enough to be below the water table and a flooded mine will stay flooded with no coal exposure to oxygen.[22] Some unusual conditions exist, however. Mines in West Virginia have produced acid runoff in mine spoils because of horizontal water movement.[23] In another example, one old mine was worked too close to the banks of the Susquehanna River. The river broke through and now leaches out sulfuric acid.[24] Despite improved techniques for new mines, the mines of the 1800's will continue to provide the hardest drainage problems to solve.

5.2.2.2 Subsidence. The subsidence or collapse of land overlying a mine occurs as a result of the gradual decay or sudden crushing, fracturing, and collapse of ceiling supports in abandoned mines. Land usually subsides over a somewhat greater perimeter but to a lesser depth than the mined area. Geological strata, aquifers, and water flow can be disrupted; the ground sinks unevenly, straining and cracking building foundations, walls, and floors of buildings, and roads, pipelines, and other structures (see Figure 5.2-1).[25] Subsidence has occurred in 30 states and is considered a hazard in 13 other states. It is most severe in the coal mining areas of Pennsylvania, Illinois, and West Virginia, but is also a serious problem in the zinc mining states of Oklahoma, Arkansas, and Missouri and in the iron-making areas of New Jersey and Washington.[26]

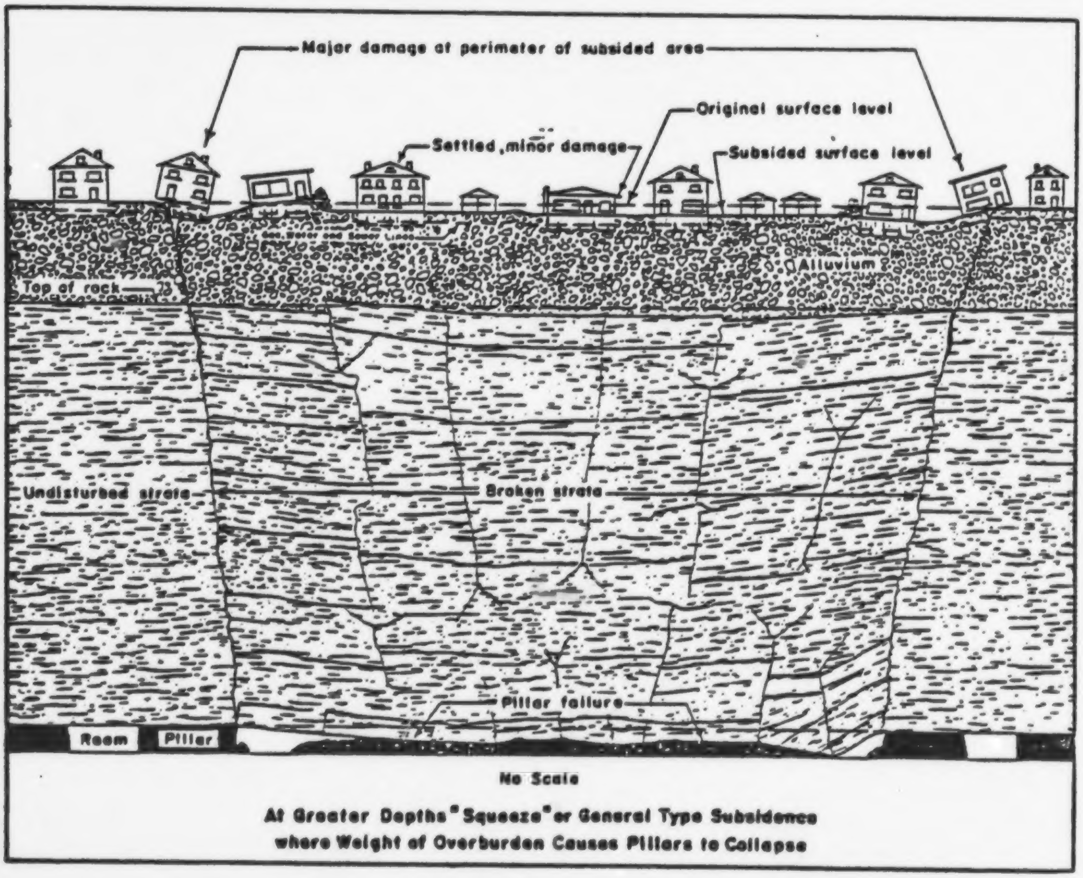
It is estimated that eight million acres of the United States are undermined and two million acres have subsided.[27] Subsidence causes about $30 billion in damages annually. Ninety-nine percent of the subsidence that has occurred is attributed to coal mining.[28] How much of this is related to nineteenth-century mining is not known, but it is likely to be a large proportion since subsidence is said to be worst in those areas that have been mined longest. In many of these areas, residential development was originally some distance from the mines, but by now urban areas--for example, in Pennsylvania and West Virginia--have grown and spread over old mined lands.[29] This increases the amount of property damage from subsidence.

Pillars of coal are left in the seam to shore up the surface and prevent subsidence. In the past during a first mining, inspectors made certain that these pillars were adequate. After the seam had been worked, however, there was often a second mining "on the way out," which was often not inspected; the temptation was strong to over-mine and leave pillars unsafe.[30] Also, even if the pillars as left appeared adequate, the gradual erosion of coal and the decay of wooden supports exposed to air and water, especially acidic water, weakened the pillars.[31]

Of the two million acres of land that is estimated to have subsided as a result of mining, about 8 percent, or 160,000 acres, are in urban areas. The Bureau of Mines has identified 260 urban areas in 28 states where subsidence has occurred or is a



Strata Failure (bending and shear) at Shallow Depths Causing Surface Potholes



At Greater Depths "Squeeze" or General Type Subsidence where Weight of Overburden Causes Pillars to Collapse

FIGURE 5.2.-1

Examples of Subsidence from Underground Mining

SOURCE: U.S. Bureau of Mines.

known hazard.[32] One example is the city of Fairmount, West Virginia, which is built on top of a nineteenth century coal mine.[33] In 1978 the land under a large apartment building and three houses subsided.[33] The buildings were damaged, gas and electric lines were broken, and some water lines burst. The U.S. Bureau of Mines reported that moisture and weathering were eroding the coal pillars under the city and a domino effect could be created because the fall of one pillar increases pressure on the next.[34]

One method of preventing subsidence is to fill the mine when it is closed. This was generally not done in the 1800's. In the early 1970's, filling was the method of choice.

> In this method, coal refuse (the shale and slate which are separated from the coal in a coal preparation plant) is crushed and then restowed in the mine cavity. This procedure--essentially one of protecting the mine surface by stuffing the mine interior--performs the double function of refuse disposal and mine support.[35]

However, this solution has largely been discarded because of evidence that it compounds environmental problems related to draining and leaching.[36] In the future the longwall mining method, widely used in Europe, may be used increasingly in the United States. In longwall mining, the section of mine being worked is supported by iron pipes. When this section is thoroughly worked, the pipes are withdrawn and planned subsidence occurs at a consistent rate. While this avoids the hazards of uneven or unexpected subsidence, the surface fractionation may adversely affect aquifers and water recharge areas.[37]

In some cases surface mining over an inactive underground mine, even one dating from the nineteenth-century, may be economically feasible. It is then possible to break through the roof of the mine and reclaim and contour both the old and new excavations at once. Obviously this is not feasible everywhere especially in those mines underlying urban and residental areas.[38]

A number of Federal agencies have responsibilities with regard to subsidence, including the Office of Surface Mining and the Bureau of Mines in the Department of Interior, the Department of Energy (Resource Applications), and the Federal Emergency Management Agency.[39]

5.2.2.3 Mine gases. Carbon dioxide, carbon monoxide, nitrogen oxides, methane, hydrogen sulfide, hydrogen, or ethane are all found in underground mines.[40] These gases can cause asphyxiation or explosion and have been responsible for the death of many miners in active mines. Since safety lamps, diesel engines, and blasting operations are possible catalysts, such explosions do not usually occur in old mines.[41] In rare cases, however, old, inactive mines can be dangerous because of these gases. Recently, in the Nortonville mine in Pittsburg, California (which was inactive but open to the public), four teenagers while exploring were asphyxiated by methane gas.[42]

5.2.2.4 Abandoned mine shafts, buildings, and equipment. A generally unmentioned safety hazard, very prevalent in old coal mine areas, is that posed by falls into unmarked tunnels and shafts, which are often covered by nothing more than a rotting wooden door.[43] The exact location of many nineteenth-century mines, which honeycomb large areas, is unknown, and it is possible to stumble without warning on or into an old vertical ventilation or entry shaft.

Many mine companies have also left behind deteriorating or rusting buildings and equipment. Because these areas are not fenced off, people, and especially children, often scramble all over both the buildings and equipment with considerable risk to their safety. Abandoned minesites, in other words, appear to constitute an attractive nuisance. Since there appears to be no sure way of keeping people from such exploration, the solution to this problem probably rests with mine owners, that is, to make certain they leave nothing behind that could cause injury or death.

5.2.2.5 Coal refuse piles. There are an estimated 3 billion tons of bituminous and anthracite coal refuse in the United States.[44] This has been heaped in piles of various sizes ranging from small to those covering several acres and reaching 200 feet in height. These piles are composed of low grade coal, slate, and shale that has been discarded during the coal preparation process, and various other things such as grease containers, rags, and timber.[45] In general, the older the pile, the more residual coal it contains, due to the less efficient mining methods of the past. Also, the more coal in the pile, the more volatile it is. There is some interest in recycling these piles, some of which have yielded as much as 60 percent coal.[46] From the huge piles of refuse located throughout coal country come at least five major environmental problems and risks: gob fires, dust, siltation, "impromptu" dams, and slides.

Because of the way coal refuse piles have been made, air can penetrate the pile, allowing oxidation of the pyrite in the refuse. This reaction gives off heat, and spontaneous combustion can and frequently does occur.[47] "Generally, not enough air is present within the interior for the whole bank to ignite, but rather it will smoulder with the interior heat slowly increasing."[48] In 1968 the Bureau of Mines found 292 fires in coal refuse banks, some of which have been burning for 50 years or more.[49] Once started, these gob fires last as long as there is combustible material to feed on, which can be decades; and because of the way the pile was built, it is very difficult to stop the fire. These longlasting gob fires result in a continuous source of air pollutants, including sulfur, released raw into the atmosphere with no opportunity for scrubbing. Under SMCRA, since 1977 refuse piles have had to be compacted so air could not penetrate to begin the oxidation.[50] Even if the pile does not burn, it is a local source of air pollution from the dust of the pile.[51] This dust can sometimes be alleviated by wetting agents.[52]

Any pile that is subjected to rain or other water flow will erode, resulting in heavy siltation of streams and rivers, in some cases rendering them no longer navigable.[53] Furthermore, there is an increase in dissolved solids in the watershed, including sulfates, calcium, carbonates, and bicarbonates, which "make water largely unpotable by altering its taste but otherwise have only minor human health effects."[54] In the mid-Atlantic region it is estimated that 30,000 tons of silt a year result from underground mining.[55]

A coal refuse pile can form an impromptu dam that over the years can block streams or rivers and create a sizeable body of water. However, since the pile was not meant as a dam, failures are likely. This situation was responsible for the collapse of a coal refuse pile dam in Buffalo Creek, West Virginia, on February 26, 1972. Alarmed about the possible effect of 3 days of rain, a deputy sheriff had inspected the dam and concluded it was ready to burst; but this was denied by the mining company and no alarm was given. Three hours later the dam collapsed, drowning 125 people and leaving 4,000 homeless.[56]

As a result of this disaster, the Army Corps of Engineers was assigned to make a survey of such coal refuse dams. The inventory was done by staff in each Corps district and was correlated in Cincinnati. It is available from that office and is called the Final Summary Report on the Inspection and Appraisal of Coal Refuse Banks and Associated Impoundments for the Appalachian states. With the results of this inventory, the Corps was to inform and make recommendations to the various states about regulating these dams,[57] and this has been done.

Another risk from these piles is realized much more regularly. Because coal refuse piles are highly unstable, they can slide, blocking streams and roads and in the worst instances, engulfing buildings. For example, on July 21, 1942, in Oakwood, Virginia, eight people were killed when a coal waste pile on a steep hillside slid into the river valley.[58] An even worse tragedy occurred in Aberfan, Wales, in 1966.

> For more than half a century, mine owners had dumped excess waste on a huge slag tipple behind this South Wales village. Every rainy day a sticky black mud washed down from the waste pile into the streets and into the playground of the new elementary school. The citizens of the town complained about the pile and its possible hazard, but their pleas went unheeded. As far back as 1947 the National Coal Board had decided it "would be far too expensive to dispose of the waste in any other way." In the meantime the heap grew to a height of 111 feet. Then on October 21, apparently lubricated by heavy rains, the entire mass slipped down a 600-foot grade, swept over the elementary school and eight other buildings, and killed 144 people. Among the dead: 116 children, virtually all the school-age children in the village.[59]

The enormous quantity of coal refuse that has built up since the nineteenth-century does not permit easy solutions. One hopeful development is the use of burned-out coal refuse, called scoria or red dog, as highway fill.[60] This solution could not, however, make use of all the refuse available. Although SMCRA has mandated that all coal refuse piles constructed after 1977 must be safe, there is still a problem of major proportions in the existence of many exposed, unstable refuse banks.

5.2.3 Coal Preparation or Washing

The problems from coal washing are not as widespread as those from acid mine drainage and coal refuse piles, but there has been significant damage in places by coal-washing practices. Coal washing was not generally done in the nineteenth-century but began around 1920 with the development of mining machines.[61] Coal washing will be discussed here since it is an enduring hazard predating such modernization of the industry as has occurred since World War II. Those mining machines were somewhat more indiscriminate than human miners. Because increased waste material was mined with the coal, the mined material was put in a "container," the coal, which is lighter, floated and the refuse, which is heavier, sank. Then the water (called "black water") that contained the refuse and some residual coal was flushed away. In many cases a nearby river was used for coal washing.

The Schuylkill River, for example, was once navigable all the way to Pottstown, Pennsylvania. Between 1920 and 1940, however, the sediment from coal washing built up and choked large sections of the river. In the 1940's, dams were built to trap this silt in order to recover and sell the coal. Nevertheless, the introduction of so much refuse not only affected the navigability of the river but also altered the water content since, among other things, both iron and manganese are water soluble.[62] In another example, a delta caused by coal washing encroached on a formerly navigable waterway and harbor in Daniels Creek, Alabama; in this case the coal washing company was held liable for damages.[63] Coal washing has imposed large costs in dredging and in creating new channels of transportation.

5.2.4 Coal Combustion

The air pollution that results from combustion of coal is well known. Those whose health was damaged by the coal-polluted air of the 1800's are long dead, but a number of legacies have been left behind.

One of the most obvious is the destruction of building facades by coal combustion's byproducts. Both metals and stone have been attacked, sometimes with costly consequences. As one example, Cleopatra's Needle, an obelisk in New York City, has had many of its hieroglyphs eroded by sulfurous acid, especially on the wind side.[64] This is an extremely serious problem in places like Rome and Athens where low grade coal has been burned for centuries. In Athens, for instance, the Vestal Virgin statues on the Acropolis have been replaced by fiberglass models to prevent total deterioration. In rare cases this deterioration may pose safety hazards. The exhaust from railroad trains, which until the 1940's burned coal, has corroded the bridges trains pass under with serious damage to bridge underpinnings as recognized in the national bridge inventory being done by the U.S. Department of Transportation.[65]

A final legacy from coal burning days stems from particle fallout. Arsenic, for example, is one of the elements that are contained in coal. The extent to which there is arsenic in surface soil as a result of coal burning and the possible effect on human health is poorly understood. With increased coal combustion in the future, the question of hazardous coating by particle fallout will take on new importance.

5.2.5 Coal Products

Compared to the amount of research done on the subjects of coal mining and combustion, relatively little has been done on coal products and their possible environmental impact. Coal-based chemistry as an area of serious research was left largely dormant after World War II as the petrochemicals industry soared. It may well have a renaissance in the future. The most useful coal product with the longest history is perhaps coke, which has been distilled from coal since the eighteenth-century.[66] (For a discussion of this procedure and its impact, please see Section 5.3).

5.2.5.1 Coal tar. Coal tar as a byproduct of coal was at first considered a nuisance. "It could not be thrown into streams because of its polluting the waters, nor could it be disposed of by burial because of its destructive effect upon vegetation, and had to be disposed of by burning."[67] It was soon discovered, however, that it could be used as a paint for wood and metal, and as a solvent in Mackintosh rubber.[68] In 1838 the uses of creosote as a wood preservative were discovered, and in 1856 the first coal tar or aniline dye was discovered, a major breakthrough in industrial chemistry.[69]

In general, advances in the chemistry of coal tar were made in England and Germany. The latter held a virtual monopoly on the production of aniline dyes until World War I forced other countries to develop domestic industries.[70] The following table shows the annual production of coal tar in four nations.

United Kingdom	1901 -	908,000 tons	1910 -	1,380,000 tons
Germany	"	590,000	1912 -	1,082,197
United States	"	272,400	"	564,000
France	"	190,680	1909 -	214,800

SOURCE: Findlay, A., The Treasures of Coal Tar (D. Van Nostrand Co., 1917), p. 12.

Therefore, the United States was largely spared the cancers associated with the dye industry until 1934, when the first case of bladder tumor was reported.[71] The likelihood of factories with dangerous nineteenth-century coal tar waste dumps in the United States is therefore lessened.

Coal tar, pitch asphalt, tar oils, creosote, anthracene oil, carbon blacks, and lignite tar, oils, and waxes are now recognized human carcinogens that can affect, through physical contact, respiration, ingestion, the skin, lungs, larynx, and bladder.[72]

Various groups likely to have been affected by (or still be at risk from) coal distillation products and combustion products include:

> workers in coke ovens, gas plants, foundries, steel plants, construction workers using tar for waterproofing, painters, tar distillers, chimney sweeps, roofers, soot burners, dry battery makers, rubber workers, makers of impregnated paper conduits, furnace men, briquette makers, creosoters, cork composition makers, carbon black producers and users; and urban populations in coal burning areas, industrial districts, harbors, railroad yards, and carbon black plants.[73]

To a large extent, the United States ran a distant third after the United Kingdom and Germany in the use of coal tar. In 1911, only two million gallons of coal tar were used, generally in paint and varnish, rubber and rubber cements, imitation leathers, and chemical manufacturing.[74] This is not a large amount, but as with arsenic, there may be some hazards arising from unsuspected exposure since the locations of factories that used coal tar (and possibly left residue in the buildings and waste dumps) are often no longer known.

Aside from the products mentioned above, coal tar provided the chemical base for numerous medicines (including aspirin, which was invented in Germany in 1899).[75] In 1887, coal tar also provided the basis of a sugar substitute, saccharine, and it has also been used for perfumes, imitation vanilla, explosives, and in photographic developing.[76] Again, with few exceptions, it was the great German chemical firms that discovered and produced the new coal tar derivatives.

With new emphasis on coal production, it is possible that there will be a resurgence of interest in coal based industry. However, the possibility of carcinogens and mutagens, not known in the nineteenth-century, may prove to be a significant constraint on this development.

5.2.5.2 Coal gas. Because coal gas was such a common form of lighting, accounts written in the 1800's often did not describe it in much detail. It appears that coal gas was first used to light a house by the Englishman William Murdock in 1795.[77] It was first used in houses in Boston in 1835[78] and was installed in the White House in 1848.[79] Because gas rates were high and progress was slow, however, it was not until 1865 that most homes could be converted from oil lamps and candles.[80] Gas was also used for street lighting and in this case was installed much earlier. Baltimore was the first American city to light a section of its streets, with New York following in 1825.[81]

Coal gas was "obtained from destructive distillation of rich coals enclosed in retorts, from which it was drawn through purifying apparatus and received in great gasometers on the outskirts of every city."[82] A ton of good quality coal produced about 10,000 cubic feet of gas.[83] However, there were impurities, such as ammonia compounds, carbon dioxide, tar, and sulfur compounds, which had to be removed before the coal could be used commercially.[84] To do this, the gas was cooled and the tar that collected was drawn into tar wells at the gas works from which it could be sold to make tar byproducts.[85] Other impurities could be washed or scrubbed out and also sold if economically feasible.[86] But the disposal of wastes from gas plants was a serious concern in the late nineteenth-century.

Coal gas did not however preserve its monopoly for long. In 1875 its dominance was first threatened by the Lowe carburetted blue gas made from oil.[87] Shortly thereafter water gas became popular and was sometimes mixed with coal gas.[88] Water gas results when steam is passed through a mass of incandescent coal or coke. This serves to break up the steam, and the oxygen unites with the carbon in the coal, forming carbon monoxide. The gas is still not light producing and is subjected to a spray of petroleum for that purpose. It then goes into a superheater, which breaks down the heavier hydrocarbons and makes it stable.[89]

The eventual death blow to coal gas came with electricity. By 1882 Edison's dynamos were supplying electricity to parts of New York City. Gas lighting remained in use until about 1914,[90] partly because in 1886 the Welsbach burner or gas mantle was invented, which provided an incandescent light that could compete with electricity.[91] It was considered a better alternative than early electricity with its complex wiring and frequent power outages.

The coal gas was piped in from the gasometers in cast iron mains or in smaller, wrought iron pipes. They were "usually laid deep enough to be under the frost line, and are kept away from car tracks and underground obstructions as much as possible."[92] Occasionally, the mains had to be drained of "drop water", which was condensed water and various hydrocarbon vapors.[93]

No mention of the obsolete coal gas pipe system, could be found in the literature—neither what was done with it nor whether it was or is a nuisance or constitutes a hazard. In some cases it may have been used for natural gas heating.

The same is true for pipes in old houses. In a book on historical preservation, gas fixtures and pipes are discussed with no mention of possible danger arising from them, either as is or when they are restored to actual use. The only warning in the book was that coal gas leaks are easily detected by the smell, and, since such is not true of natural gas, extra precautions must be taken.[94] The steps recommended to prove that gas was used in a building were to check for capped gas butts in places like back corridors, attics, cellars, and butler's pantries.[95] Ornamental plaster medallions in the ceiling can mean a gas fixture had been there. The conclusion was that "because gas pipes were run within the walls and did not show, it is highly improbable that they were ever entirely removed when electric lighting was installed in a formerly gaslighted building."[96] Although it is unlikely that there is any significant hazard associated with coal gas pipes, they may still contain hydrocarbon residues that should be handled with care.

5.2.6 Conclusions

There are major environmental problems resulting from nineteenth-century mines, including acid drainage, affecting thousands of streams, and ground subsidence, which affects or threatens millions of acres and the buildings and physical infrastructure associated with this land, as well as aquifers underlying it. Since there were coal mines in about 28 or 30 states before 1920, these problems are widespread although they vary with the geology of the region. These problems are now well recognized and programs have been initiated to attempt their mitigations. However, continuing research is needed to develop better ways of dealing with environmental problems related to coal mining. It is highly recommended that EPA undertake such research.

Environmental and human safety problems associated with mine refuse piles (gob fires, dust, siltation, hazardous dams, unstable piles) are also widespread and severe. Less severe but also less well recognized hazards associated with mines include abandoned shafts, buildings, and equipment that may cause falls and other injuries.

The air pollution from nineteenth and twentieth-century coal combustion also left behind some legacies in the form of damaged building facades and bridges, and dispersion of air-borne particles containing arsenic and other toxins; however these have probably been far outweighed by twentieth-century pollutants. . .Coal tar is now known to contain carcinogens, and there may be some residual quantities in facilities used in the 1880's to produce a wide range of coal distillation products, such as coal gas used for illuminating and heating. Many coal-derived products were superceded by petrochemical products. However, the future may see a resurgence of interest in coal-based chemistry, and industry experience with such products and their environmental, safety, and health impacts may merit further investigation.

5.3 THE IRON IN AMERICA'S SOUL

5.3.1 Summary

In the last quarter of the nineteenth-century, the U.S. became the world's leading producer of iron and steel. In 1900, it mined 26 million long tons of iron ore and produced 6.7 million L.T. of bessemer steel and 3.4 million of open hearth steel.

Every step of this process, from mining to steel shaping and finishing, has left behind residual environmental problems and hazards (see Figure 5.3-1). These have received much less attention than the effects of the coal industry. In part, this may be because the steel industry continued to be (at least until recently) a valuable, powerful, and highly integrated industry--firmly identified with its nineteenth-century roots, operating and exerting political influence in the regions which it most directly affected in the 1800's. Much of the information needed for historical assessment is considered proprietary. Secondly, the nineteenth-century pollution is hidden underground, under water, and under larger mountains of twentieth-century wastes.

If a reinvigoration--modernization, "reindustrialization"--of this industry is going to occur there may be massive rebuilding or dismantling of century old facilities or attempts to reclaim land areas and clean up old wastes. Thus it becomes important to understand what went into those wastes before the memory of living men.

5.3.2 A Century of American Iron and Steel Production

From 1800 to 1900, the American iron and steel industry grew from infancy to adulthood. By 1900 the United States was the world's largest producer of iron and steel. And iron and steel, with the maturing of the industrial revolution and the advent of railroads and steam ships, had become one of the basic supports of the world economy.

The United States had abundant resources of both iron ore and high quality coking coal, and these resources were located near waterways and natural transportation corridors. The population of the United States grew, during this century, from under four million people to 96 million, its cities were built, and it became an industrialized nation.

During the first quarter of the century, American blast furnaces were small community operations producing cast iron and wrought iron for local use. Steel was a specialty metal, and the world production of steel was less than a single day's production from a modern steel plant. During the second quarter of the century, blast furnaces became larger and more sophisticated, but iron was still largely a local industry; the maximum production of an American blast furnace in 1850 was 150 tons per week.

The momentum increased rapidly during the third quarter century, and by 1875 the growth of steel production was rapid; new processes and new alloys followed each other swiftly. Most of the present day environmental problems which can be traced to the nineteenth-century derive from this last period.

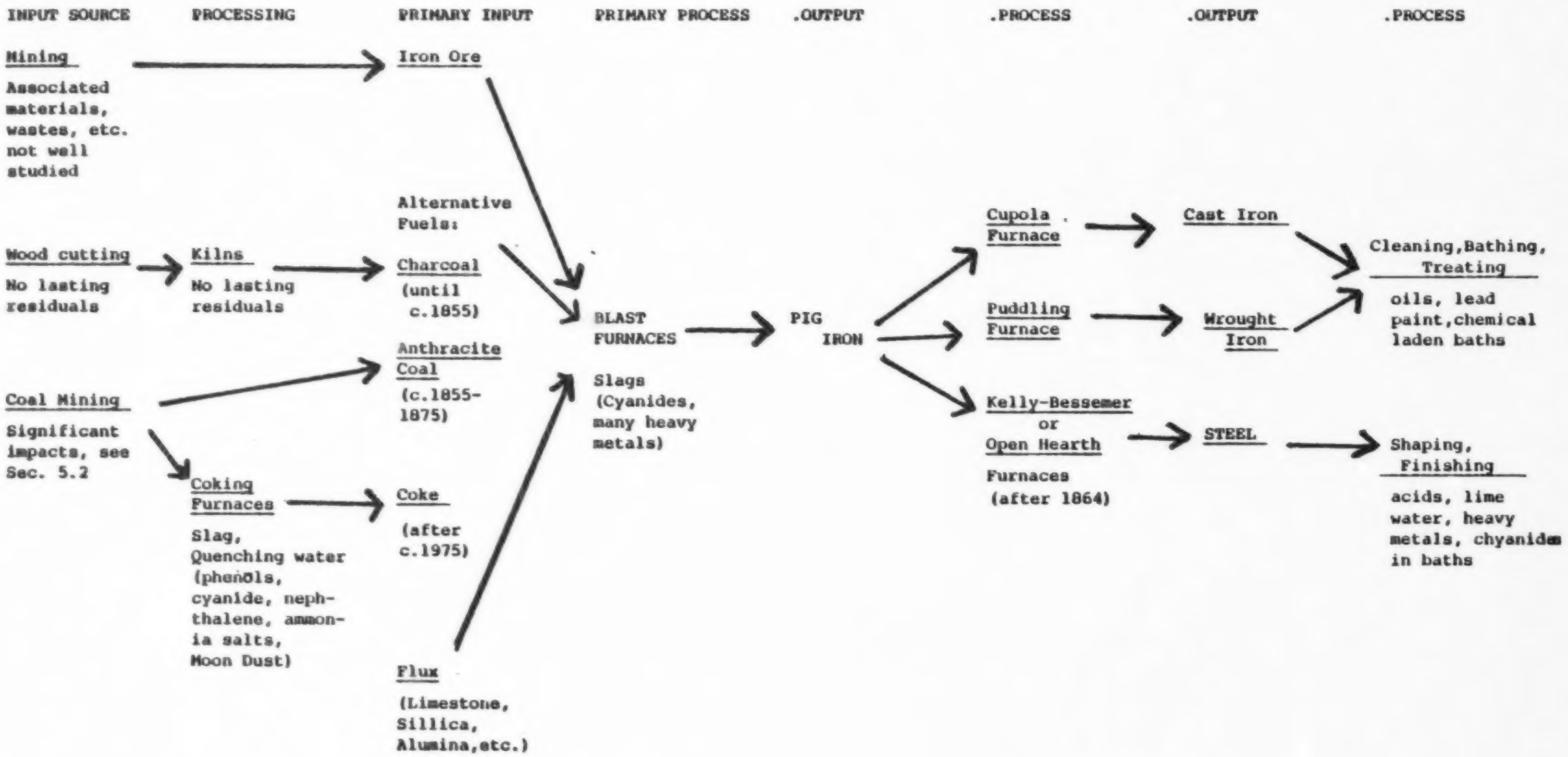


FIGURE 5.3-1

Schema of Iron and Steel Processes

By 1900, America's production of iron and steel was as follows:[1]

PRODUCT	AMOUNT/LONG TONS
Iron Ore	25,917,393
Pig Iron	13,789,242
Bessemer Steel	6,684,770
Open Hearth Steel	3,402,552
Crucible Steel	100,562
Tin Plate/Imported	60,386
Tin & Tern Plate/Produced	302,665
Open Hearth Steel Rails	1,333

In 1890, approximately 82 percent of the pig iron produced in the United States was produced in five states--Pennsylvania, Ohio, Alabama, Illinois, and New York. Their production as of that year:[2]

STATE	IRON PRODUCTION
Pennsylvania	4,945,169
Ohio	1,389,170
Alabama	914,940
Illinois	785,239
New York	369,381

The most extensive long term effects of the nineteenth-century iron and steel industry which will be discussed later will be found in these five states. However, the search for such effects will be greatly complicated by the fact that these areas have remained leading centers of the iron and steel industry until the twentieth century. In some cases, even the blast furnaces are still being used--or were used up until World War II.

To determine the residual environmental effects of nineteenth-century iron and steel production it is necessary to examine both the inputs (raw materials and fuel) and the outputs (products and byproducts) of the entire industry, from mining to final products. Subsection 5.3.3 describes the raw materials used in iron and steel production, and where they came from Subsection 5.3.4 deals with production of iron and steel. A final subsection 5.3.5 summarizes environmental problems which may have survived to the present and suggest some actions which should be considered.

5.3.3 Major Inputs to Iron and Steel Production

Three kinds of raw materials were and are used in production of iron and steel: iron ore, fuel (which acts simultaneously as a reducing agent to separate oxygen from the ore), and flux, which is material introduced to combine with and remove impurities.

Iron ore. Iron ores are iron compounds mixed with a "gangue" of earthy materials; in other words, iron ore as it is extracted from the ground is a mixture of iron rust and dirt. The chemical and physical properties of iron ore from each mine are different, and different parts of the same mine can also yield ores of different quality and properties.

Physically, ore ranges from soft beds of finely divided oxides to hard, flint like deposits. The hard deposits were (and are) more expensive to mine, and the product is so coarse that it must be crushed before being charged into the furnace. But once crushed these ores are highly desirable since they result in only small loss in flue dust. Fine ore is easier to mine but tends to cause irregularities in the furnace and to be carried off in flue gases.

The most commonly used iron ores are (chemically) either oxides, carbonates, or silicates of iron. The oxides are by far the most commonly used for blast furnace smelting. They are compounds of iron and oxygen (Fe_2O_3 and Fe_2O_4) containing 70% and 72.4% iron respectively. Iron carbonate ($FeCO_2$) contains 48.3% iron, and iron silicate ($FeSiO_2$) contains only 42.4% iron.

The iron oxides yield metallic iron when the oxygen is removed; the carbonates and silicates when carbon dioxide and silicon dioxide are removed.

The "gangue" or earthy matrix usually consists mainly of silica with varying proportions of alumina. There are generally also a number of basic compounds present, most commonly lime, magnesia, oxides of manganese, and alkali compounds.

The richest, and also the rarest, form of iron ore is magnetite, one of the iron oxides already mentioned (Fe_2O_4). It is a heavy, generally very hard steel grey ore. The most widely distributed form of iron ore however is Hematite or Red Hematite, which is identical with common red iron rust. (It takes its name from the Greek word for blood, "haima.") Hematite (Fe_2O_3) frequently occurs in a columnar formation resembling bundles of fibers. A softer form called limonite is a hydrous hematite ($2Fe_2O_3 3H_2O$)--in other words, it contains water--and is found largely in bogs or meadows. The so-called "brown hematites" are hydrated to varying intermediate degrees and are yellowish-brown.

Siderite ($FeCO_2$) is a carbonate of iron, which was rarely used in its raw state in nineteenth-century blast furnades, but was subjected to a preliminary calcination to remove the carbon dioxide (CO_2), leaving iron and oxygen in the form of a hematite.

The third kind of iron ore, iron silicates, rarely occur naturally in sufficient quantities or richness to warrent their use as ores. They are however present in the form of cinder from heating and puddling furnaces (terms which will be explained later) and as slags from steel melting or other refining furnaces. It is this by-product that was often charged back into blast furnaces. These materials rarely contain more than 55% iron; they also contain silicon oxide (SiO_2) which needs to be "fluxed" and produces much slag. These compounds were generally mixed with richer ores which produced less slag.

There are also trace elements in iron ores. The most common are phosphorus, sulfur, and manganese. Phosphorus is generally in the form of a phosphate of calcium called apatite ($Ca_2P_2O_3$). Apatite also frequently contains chlorine and flurine. Sulfur occurs most commonly in the form of pyrite or marcasite, both sulphides of iron with the formula FeS_2. Oxide of manganese also occurs frequently, as black layers or lumps scattered throughout the ore, particularly in ore from the southern United States.

Oxides of aluminum, calcium, magnesium, and the alkalis never enter into the finished iron. They become part of the slag, or rock waste material from the blast furnace. Silicon, sulfur, and manganese do enter the iron, in quantities which vary with the operation of the furnace and can therefore be controlled to some extent by the ironmaster. Practicially all of the phosphorus present in the furnace entered into the pig iron. This caused a problem when the Bessemer process for steel production was developed, after 1857. In the Bessemer process, none of the phosphorus can be eliminated, and at the same time Bessemer steel must contain less than 0.1% phosphorus. Therefore, after the Bessemer process came into use, iron ore was classified as either Bessemer or non-Bessemer ores, the former containing no more phosphorus than would constitute 0.1% of the steel.

An understanding of the nature of the many iron ores found in the U.S., and their location, can aid in evaluating the potential environmental residues of iron and steel production on a regional basis. We have therefore provided further information about the location of these ores in Appendix 1. This indicates where nineteenth-century iron mining was conducted.

The data in Appendix 1 suggests that in the nineteenth-century comparatively small land areas contributed the bulk of iron ores. Chief among these areas were the Lake Superior region, the Lake Champlain district of northern New York, Lebanon County in Pennsylvania, eastern Alabama, and western Georgia. Census data from 1890 and 1891 further substantiate this concentration of iron ore production in a limited number of states.

Fuel. In order to transform iron ore to metallic iron, the oxygen needs to be removed by chemical reduction, or smelting. In some cases, other elements present in the iron ore, such as sulfur or phosphorus, must also be removed before the iron can be used commercially.

All iron smelting is based on the fact that oxygen has a greater affinity for carbon than it does for iron. If the ore is treated suitably in contact with carbon, the carbon unites with the oxygen to form a gas, leaving the iron behind. The reactions take place most readily under extremely hot conditions.

Carbon exists in a number of forms that burn readily; therefore the reactive element is also the source of heat. The three carbon compounds most commonly used in the commercial production of iron are: (1) charcoal; (2) raw coal; and (3) coke.

The earliest form of carbon used in the commercial production of iron was charcoal, an amorphous form of carbon produced by partially burning or oxidizing wood or other organic matter in large kilns from which the air has been excluded. In Europe and England, charcoal furnaces had largely been replaced by coke fired furnaces by the beginning of the nineteenth-century. However, in the United States, due to the relative availability of wood, charcoal remained the chief blast furnace fuel until 1855. For the period between 1855 and 1875, the leading blast furnace fuel was raw anthracite coal. After 1875, coke (coal that has been heated in a closed oven to remove the various gases) became the predominant blast furnace fuel.[3]

Charcoal continued to be used in some areas long after the advent of anthracite and coke, and even continued to be the predominant fuel in some areas. Alabama, for example, did not have a working coke iron furnace until 1876.

When wood is heated without contact with air it breaks up into certain volatile products and a fixed carbonaceous residue. The volatile matter is chiefly pyroligneous acid and wood tar, and composes between four and twenty percent of the initial volume of wood with another four to six percent being moisture. Less than four percent is left behind as ash. Early processes of charcoal making involved slow burning of a pile of wood covered with earth. A modification of this involved placing the wood in a large closed oven or furnace heated either by internal combustion or by a separate fire conducted in flues around it. By products were allowed to escape into the air or were dumped on the ground. However, it is highly unlikely that any significant amount of these byproducts would remain after a hundred years, and in any case they were not hazardous.

Later a process was developed that recovered the volatile matter given off in the production of charcoal and used it to make commercially valuable substances. After refining, the pyroligneous acid was used to obtain methyl alcohol or methanol, acetone, acetic acid and several other substances. The tar yielded guaiacol, solvent oil and pitch.

Robert Forsythe, in 1909, described the typical operation of one of these byproduct retorts in the production of charcoal:[4]

> The making of charcoal in retorts at the Algoma Steel Company plant at Sault Ste. Marie is conducted as follows: The retorts consist of rectangular, horizontal shells 46 ft. long, 6¼ ft. wide, and 8 1/3 ft. high, made of 3/8 inch doors, which are capable of air-tight sealing. They are set in brick walls like a boiler, and have a fireplace at each end with fuels leading to a stack so arranged as to heat the retorts evenly. The wood is split and seasoned, then loaded on trucks and run into the retort, where it is subjected to heat for 24 hours, 18 or 20 of which it is at the full temperature of carbonization. The distillation products are led to the by-product plant for the recovery of alcohol, acetic acid, tar, etc., and the gas is sent to boilers to raise steam. After the distillation is complete, the trucks are pushed into the first cooler. The coolers are duplicates of the retorts. After a stay of 24 hours, the trucks pass to the second cooler for 24 hours, when the charcoal is ready for the blast furnace. This system obviates all rehandling of materials, as the wood is not touched

after it is placed on the trucks until as charcoal it is charged into the furnace.

The charcoal itself retains the structure of the original wood. It is black in color, very light and extremely porous. It is not readily crushed by ordinary pressure, and once ignited, it burns without a flame. There do not appear to have been any hazardous byproducts of charcoal manufacture which would still be around after 100 years.

About the third decade of the nineteenth-century, it was found that iron ore could be smelted in a blast furnace with anthracite coal as a fuel. This discovery gave impetus to the iron industry in eastern Pennsylvania, where anthracite coal was abundant.

Anthracite contains very little volatile matter. The fixed carbon usually amounts to at least 90 percent.

The development and modification of the hot blast furnaces made possible the use of raw anthracite coal. The great heat of the ascending gases coke the coal as it falls in the furnace. However, raw coal possesses a great quantitity of sulphur and other ingredients damaging to the final iron. Large amounts of sulphur present in the coal caused wrought iron to be 'hot short', that is, incapable of being worked into shape while hot because of either crumbling or breaking. Development of hotter blast furances made it possible to remove some of the sulphur with a suitable flux, precipitating it as calcium sulphate in the slag. However, anthracite coal was the major blast furnace fuel for only two decades, after which it gave way to coke.

Coke is the solid residue resulting from the distillation of bituminous (soft) coal. It was first used extensively as blast furnace fuel in the eighteen-century in England, where charcoal was becoming increasingly scarce, and had begun to replace charcoal there before the American Revolution. In the United States, where wood continued to be plentiful, charcoal continued to be the predominant fuel for blast furnaces until the middle of the nineteenth-century.

The discovery of vast beds of coking coal in western Pennsylvania made it possible for that area to become, during the last quarter of the nineteenth-century, the foremost area of iron production in the world.

By the end of the nineteenth-century, fully 90 percent of the blast furnaces in the United States used coke as a fuel. Not all soft coal could be used to produce coke, but bituminous coal was much more plentiful and easily accessable than anthracite. By the middle of the nineteenth-century, it was cheaper to produce and easier to transport than charcoal. There were still a few areas in the anthracite region that continued to use anthracite coal--or to mix anthracite coal with the more expensive coke, and some areas, particularly furnaces in the northwest area of the United States continued to use charcoal, but by the end of the century, coke had become the almost universal furnace fuel.

The production and burning of coke may have left localized but significant hazards that could have remained latent until the twentieth-century. Coking coal is a process analogous to the production of charcoal. In both cases, the process consists of heating the material in the absence of air to a temperature at which volatile matter is driven off without the combustion of the solid carbon. The remaining solid carbon, together with the mineral matter comprising the ash, constitutes the blast furnace fuel. In the case of coke, the volatile materials being driven off consist chiefly of hydrocarbon gases. The solid residue contains the non-volatile or 'fixed' carbon, along with the ash, the phosphorus and the sulphur.

The earliest method of producing coke was similar to the early method of charcoal production. The coke was simply piled in mounds and burned in the open air. The next stage was the use of kilns or ovens to produce coke, from which the volatile matter escaped as gases. The coking oven used in the nineteenth-century was usually the behive oven, so named because the early forms resembled behives. They were dome shaped, usually about 12 ft. in diameter and 7 ft. high inside, built of firebrick and clay mortar, with iron-framed doorways. The dome shape made the structure rigid and focused the heat on the coal loaded within. There was an opening about 15 inches in diameter at the top of the dome through which the charge of raw coal, generally about 5 tons, was dropped into the oven. The charge within was leveled and the door bricked closed to within an inch of the top. This gap was left as an inlet for air.

The beehive oven was not allowed to cool down between charges. When a new load of coal was charged into the oven, the volatile gases began to distill off at once. As the mass gathered heat from the brickwork, the temperature rose above the ignition point of the gases and they began to burn in the space above the charge. Air was drawn in through the slit in the dor, and the gases themselves passed out of the opening in the top of the oven. The burning gases continued to raise the temperature of the oven, and the distillation progressed from the top to the bottom of the layer of coal. The coal fused into a pasty mass. During the distillation process, it increased in volume, rising several inches in the oven. Maximum swelling of the coal occurred about 3½ hours after ignition. As the volatile matter escaped into the air, leaving the carbon behind, the mass resolidified and shrank between 20-25%. Generally the entire coking process took about 48 hours. The charge was about 5 tons and lay 23 inches deep. BEtter grades of coke, such as foundry coke, required a longer cooking period. For foundry coke, a charge of 6 tons was piled 27 inches deep and allowed to distill for 72 hours.

Once distillation was completed, the door was torn down and the hot coke was partly cooked by a stream of water. This caused the mass to contract and split up in all directions. It was then drawn out through the door and further cooled with water. The oven was then ready for the next charge.

This quenching of the coke produced a contaminated wastewater containing among other substances, tars, phenols, cyanide and napthaline. After years of use a considerable amount of these substances could build up in the soil or river sediments where the quenching water was dumped.

There are thousands of abandoned beehive coke ovens around the country. The greatest amount of coke was produced in the Appalachian district, which includes the iron producing states of Pennsylvania, Ohio, Virginia, West Virginia, Kentucky, Tennessee, Georgia, and Alabama. There were about 7,300 beehive coke ovens in operation in West Virginia alone by 1900.[5]

Since many coking ovens were associated with blast furnaces owned by the same company, another potential hazard was the reuse of the coking waste water to quench the molten slag from the blast furnace. This would saturate the slag with harmful byproducts of the coking process which could leach out into the groundwater from the slag.

Coking waste also contains ammonium salts and cyanide salts, which may remain on the site of abandoned coking ovens or in areas where coking wastes were dumped. These salts could also have leached into the groundwater supply.

At the very end of the nineteenth-century, a new type of coking oven came into use in the United States. This was the byproduct coke oven, designed to capture for economic use many of the chemical byproducts of the coking process. It also however produces a large quantity of potentially hazardous waste products that would remain in concentrated form for a long period of time.

The first byproduct coke oven was built in the United States in 1893 in Syracuse, New York. For most of the nineteenth-century, there had been two entirely separate coking processes signed to meet separate economic needs. The sole purpose of the coking process that developed hand in hand with the iron industry was to produce fuel for the blast furnaces. This process drove out the volatile matter from the coal and reduced the sulphur content. There was a second process for treating coal in order to obtain gas from the volatile matter to burn for illuminating purposes. For most of the nineteenth-century, these two processes were entirely unrelated. It was only in the last decade of the nineteenth-century that there was a practical means available to American industry to obtain the coke required for iron-making in the same process that saved and used the volatile matter.

But there was resistance within the iron industry to the use of byproduct coke for a number of years, because it was considered to be inferior to beehive coke.

The triggering factor in the conversion to byproduct coke was the first World War. In 1913, only about a third of the coke used in the iron-making process was byproduct coke; by 1919, nearly two-thirds of coke so-used was byproduct coke. By 1928, over 90 percent of the coke used in the iron industry was byproduct coke.

Several different types of coke ovens were used in the United States in this period: the Otto-Hoffman, the Semet-Solvay and the Koppers. The difference was chiefly in the details of construction--the arrangement of the heating flues, the preheating of the gas and the method of brining air into the heating flues, for example. All the forms are charged (i.e. filled with raw coal) by overhead larries and discharged by a mechanical pusher which forces the coke out of the retort. The coke was then quenched with water outside of the oven itself to prevent heat loss to the coking oven. The used quenching water, containing such trace chemicals as phenols, cyanide and napthaline, became part of the waste stream. There were apparently three common methods of disposal of this quenching water--(1) it was flushed into a nearby stream or body of water; (2) it was reused to quench the molten slag from the blast furnace; (3) it was allowed to soak into the ground.

Each of these three disposal methods could have left hazardous concentrations of trace chemicals that would still be present today. In the case of water dumping, likely areas of concentration could be in the sediment at the bottom of streams and rivers, in larger concentrations behind dams or in natural areas of deposition, and in areas where dredging waste has been dumped or used as fill.

In cases where coking waste was reused to quench blast furnace slag, continuing contamination would be more insidious. Depending on the nature and composition of the slag pile, trace chemical contaminents would have permeated or chemically combined with the slag to different degrees. In some cases, this material could be held harmlessly in stable chemical composition with the slag; in others, it could be continuously leaching out into the groundwater supply.

Coking wastes dumped on the ground could still be present in some area or be continuously leaching out into the groundwater. Physical testing of the areas around old and abandoned coking ovens has not been done on any significant scale. An evaluation of the hazard presented by disposal of coke quenching water would require identification of individual production sites, determination (if possible) of method of disposal through use of historical sources and testing of the affected area(s).

Sources of historical data are difficult to find or non-existent, particularly in the case of abandoned furnaces. Even twenty years ago, when blast furnaces went bankrupt, they were not required to leave any records of what they had done with their waste stream, and this would have been one of the last concerns of a nineteenth-century entrepeneur, particularly one in trouble. The concept of environmental degradation and industrial accountability for it is of recent origin in the United States. Few historical discussions of industry even consider the question of waste products or waste disposal. Economically useless byproducts simply disappear from the discussion.

The Otto-Hoffman by-product coke ovens were introduced in Europe in the 1880's. The retorts are built of firebrick in batteries of about 50, each one about 33 ft. long, 6 ft. high, and 16-24 inches wide, and closed at each end with airtight doors. Intervening walls are about a foot thick and contain flues for distributing the heat used to perform the distillation. The covering arch has three openings for charging coal and two for conducting away the products of distillation. These volatile byproducts passed into a condensing plant, where the tars, ammonia, etc. were precipitated out. A part of the purified gas, usually about a half, was returned to the supply pipe of the ovens to be distributed and burned in the flues around the retorts. Regenerators are used for heating the air used to burn the gases to the required 2,000 degrees F. The products of combustion pass up the vertical flues, along the horizontal, and down the opposite checkers--from there out the chimney and into the air.

There were a number of impurities and structural differences in bituminous coal from different beds that affected the quality and the composition of the coke--and the resulting waste stream. Cokes differed in such things as impurities, resulting ash content, strength of structure and presence of phosphorus and sulphur. Some areas, such as Connellsville, Pennsylvania, and Pocahontas, West Virginia were known for producing coal that yielded a strong, hard coke that was low in phosphorous.

When any fuel is used in a blast furnace, there are impurities. The chief impurities in coke of concern to the nineteenth-century blast furnace operator were sulphur and phosphorous. Sulphur is always present in coal and can be combined with bases in the form of sulphates, with iron in the form of pyrite or in composition with the organic constituents of coal. Up to thirty percent of the sulphur present could be removed by the early byproduct ovens either as suluretted hydrogen or as a bisulfide of carbon. Phosphorus present in coal occurs combined with bases as phosphates, especially the phosphate of lime (apatite). These phosphates were not distilled out by the byproduct ovens, but were concentrated with the ash, and hence represent a higher percentage of the coke than of the original coal. Coals that were high in mineral matter such as slate and pyrite were sometimes washed and then crushed before coking to produce a stronger coke.

The crude products resulting from the treatment of the gas stream and the condensates in a byproduct coking oven are tar, ammonia liquor, light oil, coke oven gas, ammonium sulphate, napthalene, creosote, and pitch. Ammonia liquor and lime sludge produced by byproduct coke ovens are considered hazardous wastes. The heavy fractions of the tars produced, or the decanter tar bottoms, are especially hazardous materials since they contain cyanides. These heavy tars were often disposed of by simply dumping them on the ground. These heavy tars would remain undecomposed after a hundred years. There are cases on record of tars oozing up from the ground at steel plants, where they have been dumped over the years.

Cyanides were produced to a greater or lesser extent in all phases of the coking process. Any accumulation of coking oven wastes should be checked for the amount of cyanide contamination present. Cyanides present in the coke also caused contamination from the blast furnaces at the time of burning.

Another potential hazard associated with old or abandoned byproduct coking ovens is the possible presence of a substance called "moondust" in the gas lines or flues. This substance, a precipitate of coal gas, does not decompose appreciably over the time span being considered. Chemically, it is composed of iron, sulphur, ash, hydrogen sulfide, cyanide, thiocyanate, ammonium salts, phenol, sulfates, chlorides, trace heavy metals. The iron, cyanide, phenol, sulfates, chlorides, and heavy metals would be present as leachates in water seeping through this material.

In present day coking plants, this material is periodically cleaned out of the pipes, generally annually. It is produced in relatively large quantities by each coking oven. A small modern coking oven produces about 5 tons per year; a large plant could produce up to 1500 tons in a year. Moondust is both poisonous and tricky to handle; it tends to burn spontaneously on handling. Current practice is to dispose of moondust through landfills, but what was done with it in the nineteenth century is not known. It can be fairly assumed that once it was cleaned out of the piping, it was disposed of in much the same way as waste quenching water: it was either piled up on the ground, thrown on to the slag heap, or dumped into a convenient body of running water.

This material could be present in abandoned coking ovens (since few industries cleaned up their mess when they went bankrupt) or it could be contributing to leachates from slag heaps or dumpsites. There are areas in Pennsylvania where people have had to put filters on their wells because of the high quantities of phenols in the water. Since these are the old iron and steel producing areas of Pennsylvania, contamination could easily date to the late nineteenth century.

To get some idea of the number of byproduct coke ovens used in the United States at the end of the nineteenth-century, we can look at the byproduct coke production for the years 1905 through 1908.[6]

	1905	1906	1907	1908
No. Ovens Existing	3,159	3,603	3,892	4,007
Coke Produced/Net Tons	3,462,348	4,558,127	5,607,899	4,201,226
Average Production per Oven/Net Tons	1,159	1,356	1,472	1,142
Percent Total Coke Production	10.7	12.6	13.7	16.1
Total Coal Used, Net Tons	4,628,981	6,192,086	7,506,174	5,699,058
Average Yield, per cent	75	73.6	75.0	73.7

SOURCE: Forsythe, Robert, The Blast Furnace and the Manufacture of Pig Iron, 2nd ed. (New York: David Williams Co., 1909).

Coke was made in all seven of the bituminous coal fields of the United States worked during this period. The greatest amount of coke was produced in the Appalachian district, particularly in the states of Pennsylvania, Ohio, Virginia, West Virginia, Kentucky, Tennessee, Georgia, and Alabama. These are the states that have the highest probability of residual contamination from nineteenth century coke production.

Fluxes. The final major ingredient of the burden, i.e., the total material put into the furnace, was the flux. The flux is any material introduced into the furnace to combine with impurities in either the iron ore or the carbon compound used as fuel. The flux, plus the collected impurities, forms a waste material known as slag. Chemical composition of slags will vary with the type of iron ore used, the type of coke or coal used, the flux and the design of the smelting furnace. Sometimes, the slag was recycled into other uses, such as aggregate for concrete or processing into mineral wool, but most blast furnace slag was simply heaped on the ground.

The most common flux materials are limestone, calcium carbonate, dolomite and occasionally oyster shells. Fluxes were selected according to the material to be fluxed. If it was basic, such as lime, magnesia, or similar alkaline materials, the flux needed to be acidic, such as silica or alumina. Acid gangues required basic fluxes. Most gangues were acidic to a greater or lesser extent; therefore the most common flux materials were basic.

Any of the metallic oxides could act as a flux for silica and alumina, but the least expensive, and hence the most generally used, was lime (CaO). Lime was introduced into the furnace in the form of calcium carbonate ($CaCO_3$) usually in the form of limestone.

At temperatures above 1100°F, the limestone begins to decompose into lime (CaO) and carbon dioxide (CO_2). The carbon dioxide joins the current of gases and passes out of the blast furnace, combining along the way with any coke it encounters at high temperatures to form carbon monoxide. This carbon monoxide would have been a hazardous air pollutant in the nineteenth-century, but would not be of concern at the present time.

The lime continues to descend to the zone of fusion, where it unites with any free silica and alumina to form slag. Some of the silica and alumina present in the iron ore may already be in combination with an equivalent of bases. The lime also combines with sulphur in the charge. Generally, if ten percent or more of the sulphur in the original charge was allowed to enter the iron, it was enough to make the pig iron unsuitable for most purposes. Therefore, most of the sulphur from the charge was removed by combining with the lime and forming calcic sulphide, which then entered the slag.

The following table gives a general idea of the composition of fluxes most commonly used in American blast furnaces in the nineteenth-century. The second column (R_2O_3) indicates the presence of any trace element combined with oxygen.

ANALYSIS OF FLUXES

Limestones & Dolomites	SiO_2	R_2O_3	$CaCO_3$	$MgCO_3$	S	P
Annville, Pa.	0.64	0.72	96.78	1.23	0.012	0.004
Wrightsville, Pa.	1.44	2.12	82.55	13.50	0.032	0.020
Maryland	0.78	0.86	97.48	1.21	....	....
Kelley Island, Lake Erie	1.15	1.04	82.41	15.64	....	....
Avondale, Pa. (white)	1.50	1.36	66.50	30.40	0.004	0.005
Avondale, Pa. (grey)	3.94	2.80	59.51	33.26	0.132	0.019
Buena Vista, Va.	1.34	0.92	54.50	Tr.	....	....
Buena Vista, Va.	0.75	1.08	29.80	21.20	....	....
Birmingham, Ala.	1.75	1.20	31.70	19.00	....	....

SOURCE: Forsythe, Robert, The Blast Furnace and the Manufacture of Pig Iron, 2nd ed. (New York: David Williams Co. 1909).

Generally, the blast furnace slags were harmless. The problems were generally caused by the fact that slag heaps, particularly at the smaller furnaces tended to evolve into general dumpsites. Coke quenching waters, tars, and other waste chemicals were poured indiscriminately into slag heaps. Many of these substances were hazardous, even over the long term, and depending on the nature of the slag, can continue to leach out into the water supply.

5.3.4 Types of Iron

There are three main commercial categories of iron: (1) wrought iron; (2) cast iron; and (3) steel.

Wrought iron is the oldest form of commercial iron produced and the most chemically pure. It contains as little as possible of other elements. Two elements, sulphur and phosphorus, are particularly undesirable in wrought iron. Sulphur causes the iron to be "hot" or "red" short. In other words, the iron cannot be worked when hot because it crumbles or breaks easily. Phosphorus causes iron to be "cold" short; that is, weak and brittle when cold. Cold short iron tends to shatter easily. Sulphur and phosphorus present in many iron ores had to be eliminated during the manufacturing process.

Wrought iron has a fibrous structure and is extremely ductile. It can be easily hammered or rolled while hot. The properties of wrought iron are enhanced by fibers of slag remaining in the iron structure. This slag also assists corrosion resistance.

Wrought iron came into increasing use during the first half of the nineteenth century. By the 1860's, it was the most important form of iron in use. However, in the second half of the nineteenth-century, mild steel became increasingly important and the use of wrought iron declined. There were no major technical advances in the use of wrought iron after the 1860's.

The second oldest form of iron in commercial use was cast iron (also known as pig iron or blast furnace metal), which is an alloy of iron with any of a number of other elements, including carbon, phosporus, silicon, and manganese. These other elements can comprise up to 10 percent of the final metal.

Cast iron is a crystalline metal that is easily melted and capable of being cast into molds while in the molten state. In fact, casting is the only way this form of iron can be worked. It cannot be forged, rolled or otherwise shaped--either hot or cold. Cast iron has poor tensile strength, but very good compression.

The final commercial form of iron is steel. Steel is not one metal, but many, each with a widely differing set of characteristics. Fundamentally, steel is an alloy of carbon and iron, but it may contain other materials as well. The milder the forms of steel (those with a lower carbon content) came into increasingly widespread industrial use in the later half of the nineteenth-century.

5.3.5 Iron and Steel Production

The blast furnace is the first step in the commercial production of both iron and steel. (See Figure 5.3-1.) It converts the raw materials of iron ore, fuel (generally coke), flux (generally limestone), and air into pig iron and associated byproducts, chiefly slag and various gases. The blast furnace has been used since the 1500's, though there have been a number of modifications and changes made. The modern blast furnace reached its present form by the close of the nineteenth century.

Once pig iron comes from the blast furnace, it is subjected to further treatment by one of four processes: (1) casting; (2) puddling; (3) conversion into steel by either the Acid or the Basic Bessemer Method; or (4) conversion into steel by either the Acid or the Basic Open Hearth Method.

In the earliest blast furnaces, molten iron from the furnaces was cast directly into molds to form cookware, tools and weaponry such as cannonballs. By the end of the seventeenth-century, the cupola furnace had been developed which permitted the remelting of pig iron before casting into molds, giving a sounder and more homogenious casting. The puddling furnace, also developed in the late eighteenth century, was used to remelt the pig iron into a pasty mass which could be hammered as wrought iron.

The two processes used for the conversion of pig iron into steel, the Kelley-Bessemer Process and the Siemen's Open Hearth Process, were both commercially developed in the last quarter of the nineteenth-century. Steel had been produced earlier, but only in very small quantities; it did not come into widespread commercial production in the United States until the last decades of the nineteenth century.

Once steel had been produced, it too was further worked, either by direct casting or the formation of steel ingots. The ingots were then formed into a large number of basic steel shapes.

In the iron industry, both the raw materials (iron ore, coke, and flux) and the finished products are bulky and difficult to transport, resulting in problems of siting and transportation. Ironworks were generally located near both the source of raw materials and convenient water or rail transportation. The plants also required access to large quantities of water for cooling and quenching.

Toward the end of the nineteenth-century, large integrated iron and steel works were already becoming the norm in the industry. These integrated works consist of blast furnaces, steel works and rolling mills. Also the plants would generally have their own coking ovens, plants for crushing the ores and preparing them for the furnaces, steel foundries, and a press or forge in which steel ingots are pressed or hammered into the required shapes.

In an integrated iron and steel works, the materials move or flow from one end of the works to the other in a more or less consecutive process. The plant needs a large land area to accomodate huge masses of materials, from stockpiles of ore and fuel to large quantities of rolled and finished steel. In addition, both the smelting and the steel-making process generate large quantities of slag. By the nineteenth-century, ways were already being developed to commercially reuse a small percentage of this slag, such as cement, paving and building blocks. Still the vast bulk of this material was simply dumped on the ground or into a nearby waterway where it would not block navigation. Slag heaps would evolve into general dumpsites that became a repository for most of the waste products from the plant. Most long-established iron-working areas can show their ugly grey-brown slag piles, over which little can be made to grow. The Northern Indiana iron works piled their slag into Lake Michigan, creating new 'land' for themselves in the process.

The Blast Furnace. The primary function of the blast furnace is to reduce the ore to metal and subsequently separate the metal produced from the gangue (earthy material). The fuel, which has generally been coke since the last half of the nineteenth-century, serves as both fuel and reducing agent for the process.

By 1900 the modern blast furnace was already in use. One of the most important improvements in blast furnace design had been the application of steam engines to the blowing of the blast air and the subsequent introduction of the blast in 1828. Until this time, the air blown into the blast furnace was at its natural temperature. It was, in fact, a firm conviction among ironmakers that the cooler the blast, the better the quality and the higher the quantity of iron produced, an idea resulting from the fact that output per furnace increased in the winter. In 1828, a Scots engineer named Nielson obtained the first patent for a hot blast furnace. In 1857, E.A. Cowper used the hot waste gases from the furnace top to preheat stoves which in turn heated the cold blast air. The temperature of combustion was raised to such a degree that the whole operation was speeded up and there was a substantial increase in the output of pig iron.

The modern blast furnace is a tall cylintrical shaft which increases in cross-sectional area from the top, or throat, downwards to the bosh, or area of greatest diameter. The principal components of a blast furnace are: (1) foundation; (2) hearth; (3) bosh; (4) stack, and (5) top section.

The foundation of the furnace is required to support the entire weight of the furnace without settling. Current practice is to sink a concrete piling base, measuring about 50 feet in diameter by 20-22 feet thick. The furnace bottom, consisting of about a fifteen foot depth of firebrick, rests on this base.

The hearth is the receptacle for the liquid iron and slag. It is formed from large carbon blocks. Generally, the walls are three feet thick at the top of the furnace, increasing to five feet thick at the bottom. The bricks are stepped out from the bottom to avoid having the bricks float out. Formerly, fire bricks, rather than carbon bricks were used. However, the carbon bricks have higher refractory properties, low porosity and high density which makes them superior in resisting the scouring action of the iron and slag at high temperature.

Some experts believe that the porous nature of the old firebrick furnaces combined with the many toxic components in blast furnace gases should make these bricks unsuitable for almost any present reuse. It is currently very popular to salvage old industrial materials, particularly brickwork, for use in homes and businesses. In the case of the dismantling of an old, unused blast furnace, such adaptive reuse should probably be precluded, because heavy metals, cyanides, tars, and other substances could remain in the bricks and present a health hazard to people coming in contact with them.

A tapping hole or iron notch about 5 inches in diameter is located at a height of about 2-3 feet above the furnace bottom. When the tapping hole isn't being used, it is plugged with refractory material (generally clay) applied at high pressure into the opening. When it was time to tap the furnace, the clay was knocked away--later burned away with an oxygen lance. The cinder or slag notch is about four or five feet above the iron notch. Molten slag is lighter than iron and will float on top.

The tuyeres are situated immediately above the hearth. These are the pipes through which the blast air required for combustion is blown into the furnace. According to the size of the furnace, there are generally between 10 and 20 tuyeres, evenly spaced around the circumference. Air reaches the tuyeres by way of a refractory lined hot blast main or bustle pipe 4 to 5 inches in diameter. This bustle pipe circles the furnace and is connected to the stoves.

The furnace bosh is the zone of greatest diameter and greatest heat. It is made up of stepped bricks surrounded by supporting steel bands. It is supported by the hearth and extends upward to the stack at an angle of approximately 20° to the vertical. The mantle is a steel ring at the top of the bosh which encircles the furnace. It is composed of heavy steel plates. The mantle supports the furnace stack and pop structure. Directly above the bosh is the stack, which comprises the upper part of the furnace. The stack height has gradually evolved to between 65-70 feet, this being the optimum height for maximum heat recovery from the gas. An outer steel jacket encloses a refractory lining composed of hard-fired alumina bricks to a thickness of 3-4 feet.

It is through the top section that the charge is introduced into the furnace. Blast furnaces generally have a bell and hopper mechanism for charging raw material into the top of the furnace while minimizing the escape of top gases. The offtakes are steel pipes located in the furnace just below the bell and hopper mechanism. They conduct the top gases and join up with a larger steel pipe known as a downcomer which delivers the gas to the cleaners.

The gas issuing from the top of the furnace is heavily laden with dust derived from the ore, the flux and the fuel. Size of these particles range from about 0.25 inches to a few microns. A number of arrangements were devised to prevent this ash from choking the stove. Gases had to be cleaned of most of this particulate matter before they could be reused to heat the furnace.

The large particles could be removed by passing the gases through a downcomer pipe to large brick chamber in which the velocity of the gases was reduced to allow settling. Chambers are generally built to allow cars to run beneath them to receive the dust. Smaller particles were dealt with through the use of wet scrubbers, in which the gas was subjected to water sprays, obstruction of flow by the use of baffles insuring intimate contact with the water. These wet scrubbers produced highly contaminated water. The nineteenth-century metallurgical texts do not indicate what was done with this water from the scrubbers. It probably was drained out into a nearby river or other body of water. This liquid waste would not have been perceived as presenting a hazard to navigation. However, it would have left sediments of heavy metals, and possibly tars in the river sediment, which could be still present. This water may have been used for quenching the slag heap or the coke furnaces.

The gas scrubbers removed dust particles down to the size of a few microns. These small particles could not be removed until the early 1900's with the development of effective electrostactic dust precipitators.

The traditional blast furnace stove, the Cowper regenerative hot blast stove, was first patented in 1857. These large stoves were between 80-100 feet in height and 20-30 feet in diameter. They consisted of two sections: the combustion chamber and the refractory brick checkerwork. The combustion chamber is an open space extending the whole length of the stove and provided at the lower end with a burner. Blast furnace gas together with air is admitted via the burner, combustion takes place in the combustion chamber and the products of combustion pass upwards and over the partition wall, then downward through the checkerwork. The gases impart their heat to the checkerwork, finally being discharged to a stack. The gas supply was periodically turned off and a cold blast of air was admitted in a direction countercurrent to that of the gas. This blast of air absorbed heat from the checkerwork before being admitted to the blast furnace. Cold air and hot gases alternate through the stoves, the burnt gases yielding heat to the bricks, which in turn yield the heat to the air blast.

To keep the operation of the stoves continuous, a number of stoves are used with each blast furnace. One or more stoves are 'on gas', that is being heated by the hot gases from the furnace. Another stove is simultaneously 'on blast', that is the cold air is being heated by the heat stored in the checkers before passing into the furnace tuyeres. The usual configuration is to have three stoves per furnace--two 'on gas' and one 'on blast.' This type of stove is still in use today.

Cast Iron and Wrought Iron. The first significant production of cast iron in Europe dates from around the fifteenth or sixteenth-century, with the discovery that liquid iron could be caused to flow from the hearth of the blast furnace and that this metal could be cast into shape in a mold. The earliest recorded uses of cast iron were in the making of church bells and military ordinance.

Large products were cast by allowing the metal to flow directly into the mold; for smaller objects the metal was collected in a reservoir at the base of the furnace from which it was ladled into molds. This technique restricted casting to the site of the blast furnace. Also, given the uncertain composition of the resulting pig iron, little control could be exercised over the quality of the castings. The solution appeared to be to allow the pig iron to solidify and then remelt it in another furnace.

In 1795, William Wilkinson introduced the cupola oven to remelt solidified pig iron. The cupola oven resembles a small blast furnace and consists of a refractory lined vertical shaft into which air is supplied through the tuyeres by a blower. Charging is done through the top opening and metal is tapped from the furnace hearth at the bottom.

By blending pig iron with other materials of known composition and remelting, a cast iron of known composition could be made. Alternative layers of pig iron and coke were charged into the furnace, with coke making up about ten percent of the weight of the metal. Limestone was added to flux the ash from the coke. Heat was supplied by the combustion of the coke with the blast of air through the tuyeres.

The cupola oven removed the necessity of locating the foundry next to the smelter. For the first time, it was possible to site a foundry in a region remote from the smelting.

Wrought iron was the predominant form of iron in the early part of the nineteenth-century. Wrought iron was generally produced with the use of a puddling furnace which had been developed in the late eighteenth-century. The purpose of the puddling process was to oxidize and remove carbon and other impurities from the blast furnace pig or cast iron, thus making it malleable. Early methods of puddling used charcoal in direct contact with the iron. The charcoal served both to supply heat and react with the carbon in the pig iron. Coal could not be used in puddling. In direct contact with the iron it imparted sulfur, which made the iron hot short, or brittle when worked hot. Early iron puddling was both slow and costly, using approximately a ton of charcoal for every ton of iron produced.

The significant advance in the design of puddling furnaces came in the late eighteenth-century when Henry Cort devised a method for producing wrought iron in a reverberatory furnace. Cort's furnace involved a firegate separated from a shallow hearth by a firebrick bridge. This avoided direct contact between the fuel and the iron, so coal could be used. The hearth was hollowed out so that the iron would puddle in the center. The pasty, semi-molten metal was puddled or rabbled by the furnace men with long iron rabbles through holes in the widewalls of the furnace, thus exposing the metal to even heating.

Iron puddling was one of the most physically demanding and dangerous professions in an age not particularly known for concern with worker safety. Men worked in heat well exceeding 100°F, on floors that were both slick and spattered with chunks of molten metal. Nosebleeds and faints brought on by heat exhaustion were everyday occurances.

Yet in spite of these conditions, the puddlers were expected to work several hundred pound mass of molten metal, finally dividing it up into three balls weighing over 150 pounds each and removing these from the furnace with tongs. Once the balls were removed from the furnace, each was 'shingled' by the blows of a forge hammer to expel the slag and to form it into half-blooms. Each half bloom was then passed through the rolls, the grooves of which shaped it into bars.

The puddling furnace came into use in the United States early in the nineteenth-century. The first such installation was made at the Plumstock Works, near Uniontown, Pennsylvania, in 1817. By the 1820's, there were at least eight puddling furnaces around Pittsburgh alone.[8]

Steel Production. During the first half of the century, production of wrought iron and cast iron increased drastically. A number of factors contributed to this increase, including the development of machinery and engineering, the increasing use of iron for structural purposes and the railway boom of the 1830's and 1840's. Yet, steel production was another story.

During the first seventy years of the century, steel production remained at a minimal level. Great Britain, the world leader in both iron and steel production during this period, turned out 2.5 million tons of iron but only 60,000 tons of steel in 1850. Steel production in the United States was even more limited. In 1810, the United States only produced about 917 tons of steel. In 1831, there were only 14 steel furnaces in the United States, with an annual capacity of about 1,600 tons. In 1867, steel production had only risen to about 22,000 tons.

The last three decades of the century show a startling contrast, for both the United States and the world. In 1870, world steel production was still little more than half a million tons; in 1900 it was 28 million tons. Over 40 percent of the world's total steel in 1900, 11.4 million tons, was produced in the United States. The United States had assumed the lead in world steel production in 1889, and held on to it for the rest of the century.[9]

Accompanying the rapid increase in steel production, there was a concurrent increase in puddling (wrought) iron, but steel was being rapidly substituted for wrought iron wherever possible. This change took place over a period of less than fifteen years, as the British experience illustrates. In 1883, 70 percent of all the blast furnace iron (pig iron) produced in England was converted to wrought iron; by 1897, the percentage was down to less than 5 percent. One important factor was the substitution of steel for wrought iron in the construction of railways and buildings. Wrought iron was reverting to its oldest uses by the blacksmith, the anchorshmith and the chainmaker.

Why the rapid growth of steel at the end of the century? The answer lies in the development of the two technologies that for the first time made it possible to use stronger, more corrosion resistant steel economically on a large scale. Before the end of the nineteenth-century, steel had been considered a specialty metal, both rare and expensive to produce. The two methods of steel production then available, cementation and the crucible process, were laborious and uneconomical.

Cementation was a process whereby alternating layers of iron bars and charcoal were placed in two long cementation pots inside a furnace. They were sealed and kept at a cherry-red heat for ten days, during which time the iron bars absorbed enough carbon from the charcoal to form steel. This blister steel was of highly variable quality and brittle at the temperatures at which the metal was normally worked. Only steels produced from the purest iron ores, such as some of the Swedish ores, could be used for such purposes as surgical instruments.

Crucible steel was developed in the mid-eighteenth-century. A small barrel shaped crucible, generally 12 to 16 inches high and 8 to 12 inches in diameter was charged with cement steel broken into pieces. These crucibles were sealed and then immersed in a coke fire in a furnace holding up to 80 pots. It took 4 to 5 hours to remelt the cement steel, after this time, the pots were lifted out of the furnace. The slag was skimmed off the top and the steel teemed into a mould. The moulded ingots were later reduced to bars and forged into the required shapes.

It is highly unlikely that either of these two early processes of steel production would have left any residual environmental problems that would be of concern in the twentieth-century. Steel production was at a very limited level up to the last thirty years of the century. Neither process is used at the present time.

The modern steel age began with the discoveries of Kelly and Bessemer in the period of 1850-56 of the pneumatic process, and steel did not really begin to replace iron in commercial usage until Siemen's invention of the open hearth process some ten years later. The Siemens process had several advantages over the Kelly-Bessemer process, which is described below. It allowed a wider selection of raw materials, the composition of the bath was under better control, and scrap metal in practically any proportion could be utilized. However, steelmaking was still restricted by the requirement for non-phosphoric ores. It was not until Sidney Thomas and his cousin Percy Gilchrist devised a suitable basic lining for the converter that it was possible to treat phosphoric ores. This extended greatly the potential amount of ores available for steel production, including the large reserves of phosphoric ores in countries such as the United States, Belgium, France and Germany.

Kelly-Bessemer Process: Controversy still persists over whether the American William Kelly or the Englishman Sir Henry Bessemer should be considered the founder of the pneumatic process of steelmaking. Both worked on the idea independently, though there are tales of the two mysterious Englishmen who worked for Kelly at his Kentucky ironworks, becoming particularly interested in his 'air-boiling' process. The Englishmen left in the middle of the night, without notice and without their paychecks. Soon after this, Bessemer took out an English patent for his own pneumatic process. Kelly was then persuaded to take out his own patent, proving to the satisfaction of the Patent Office that he had already been using the same process for several years.[10]

In both cases, the principle was the same, that oxygen in the air could be used to burn out some of the impurities in iron and that iron could be refined by subjecting it to a blast of air in a specially constructed furnace. Kelly succeeded in converting pig iron directly into malleable iron in one process. He did this in a pear shaped vessel that looked very much like the present day converters.

Both the Kelly and the Bessemer processes are based on the idea that decarbonization of pig iron can be effected more readily by supplying oxygen in the form of air rather than iron oxide. This increased the speed of the reaction over a thousand times over the puddling furnace. Furthermore, it did not require extraneous fuel.

Early in the development of the pneumatic process a number of severe difficulties were encountered. The first of these was the difficulty of casting uniformly sound ingots, caused by the ebullition of gases from the solidifying metal. A remedy for this problem was found not by either Bessemer or Kelly, but by English metallurgist Robert Mushet, who was the first to make steel using the pneumatic process. He did it by adding spiegeleisen, a compound of iron, carbon and manganese or ferromanganese to the charge.

The most difficult problem was caused by the presence of phosphorus in many iron ores. It was purely by chance that Bessemer produced his first steel by using iron ore that was extraordinarily poor in phosphorus. Other steelmakers who tried to use phosphoric pig iron in the making of Bessemer steel found the final product to be unworkable either hot or cold. The phosphorus remained in the steel causing it to be extraordinarily brittle.

Bessemer tried to eliminate the phosphorus by continued blowing, probably on the assumption that since in the puddling process dephosphorization is accomplished by the presence of iron ixide slag, a sufficiently long converter blow would also form an oxide slag. This did not work.

Years later, it was discovered that the presence of a highly basic slag, which has a high affinity for phosphorus, could be used to remove the unwanted phosphorus. Since the heat necessary to sustain this reaction is derived from the oxidation of the phosphorus, it is essential that the pig iron contain an adequately high amount of phosphorus, at leat 1.5 percent. Thus the Bessemer process (the name has become common usage) was capable of working iron at either extreme-- very low in phosphorus, or very high in phosphorus. The original (acid) process could only be used with ores extremely low in phosphorus; the basic (Thomas-Gilchrist) process required extremely high-phosphorus iron.

In 1884, Sidney Thomas extended the idea of the basic furnace to the open-hearth furnace, as well as the Bessemer process, by installing a dolomite hearth in place of the silica which had been employed since its discovery by Siemens in 1863. This made it possible to use any pig iron in the formation of steel. It also made possible the incorporation of scrap in any proportion into the charge. In the Bessemer process, the maximum amount of scrap that could be used was 5 percent.

The first Bessemer steel was made in the United States in Wyandotte, Michigan, in 1864. Bessemer steel production peaked in 1906, when 13,800,000 tons were produced.

In the Bessemer process, the vessel or converter, is filled with molten iron. The vessel itself is mounted on trunions so that it can be rotated from the horizontal to the vertical. When the vessel was filled partially with molten iron, it was then rotated upright and air was pumped into the melt from below. This caused the carbon in the molten iron to oxidize and pass out with the excess air as CO and CO_2.

A converter blow involved great bellowing masses of sparks and burning gases erupting violently from the mouth of the upright converter. When the steelworkers determined, by observing the color and the intensity of the flaming mass, that the steel was ready, the converter was tilted over to the horizontal and emptied by pouring or teeming the ingots.

Ingot molds were on tracked cars which passed under the spouts. As the steel solidified, the jacket molds were stripped off the ingots by cranes. Great foaming and effervescence occurred as dissolved gases remaining in the steel came out during solidification. This foam formed a rim around the ingot that was later cut off.

Open Hearth Process: The idea of melting steel in an open hearth had undergone experimentation for many years. However, the first commercial development of the process owes its existence to two pairs of brothers, the Siemens in England and the Martins in France. Dr. Charles Siemens had developed a regenerative furnace which became the distinguishing feature of the open hearth furnace. In a regenerative furnace, the heat from burnt gases is transferred to chambers, called regenerators, through which air is subsequently passed. The heated air is then united with the flaming gases, causing them to burn more intensely. A regenerative furnace provides a more intense heat than natural flames. In 1861, Dr. Siemens first applied the principle of a regenerative furnace to an open hearth furnace. His work was not successful at this time.

At the same time, Emile and Pierre Martin were experimenting with an open hearth furnace in Sireuil, France. On a visit to France in 1864, Dr. Siemens added his regenerative device to the Martin furnace, developing the first successful open hearth process of steelmaking. This device is often referred to as the Siemens-Martin process.

The initial open hearth furnaces built in the 1860's were small 5 to 10 ton furnaces having silica sand hearths. Scrap and pig iron were charged into the furnace and the metal was melted down. Samples were taken at intervals to ascertain the metal composition. When the carbon content of the metal approached that desired, the metal was tapped. The open hearth furnaces were slow compared to the rapid Bessemer process. However, the furnace was under greater control and therefore, the process was more reliable.

The real impetus to the development of open hearth steel came with the development of a basic lining to the open hearth, as with the Bessemer converter, that made possible the removal of sulphur and phosphorus. It was the successful development of the basic open hearth furnace that made it possible for the open hearth to finally supercede the Bessemer process.

The first recorded use of the Siemens-Martin process in the United States was at the New Jersey Steel and Iron Company of Trenton, New Jersey in 1868. This furnace was apparently used only on an irregular basis. The first regularly used such furnace was built two years later for the Bay State Works of South Boston. By 1880, United States production of open hearth steel stood at 112,950 tons; by 1890, it had quintupled. In 1900, it stood at 3,805,900 tons, about half of the total production of Bessemer Steel. This large jump in the last decade of the century is generally attributed to the development of the basic open hearth process and the opening up of the Lake Superior ore fields.[11]

During the first five years of the twentieth-century, Bessemer continued to hold an appreciable lead over open-hearth steel. In 1906, the lead began to shorten, and by 1908, open hearth production began to predominate.

In many cases, elements other than carbon were added to the steel to improve one or more of the properties of the metal. These are the so-called alloy steels. Chromium in small quantities increases hardenability allowing attainment of high tensile strength with considerable ductility. In large percentages, it gives steel corrosion resistant properties. Cobalt makes steel heat resistant. Nickel increases tensile strenth and toughness.

Sir Robert Hadfield introduced manganese steel in 1888 and nickel steel in 1889. Mushet introduced a self (air) hardening steel for toolmaking in 1868. This was steel alloyed with tungsten and manganese.

Micheal Faraday had experimented in the early 1800's with alloying steel with twenty different elements. This research did not reach its fruition until much later with the development of efficient steel production by the Bessemer and open hearth methods. Steels alloyed with either chromium or nickel were used for guns, armour and projectiles in Europe as far back as the 1820's. Nickel steel was favored in heavy caliber guns. In 1891, the United States Navy adopted nickel steel armour as standard equipment after studying its use in France.

Combined chromium-nickel steels were adopted in the last decade of the nineteenth-century. America's first 16 inch guns, made of nickel steel, fired projectiles of chromium-nickel steel. These guns were used to devastating effect during the Spanish-American War of 1898 when Admiral Dewey used them in his victory in Manila Bay.

During the closing years of the nineteenth-century and the first years of the twentieth, alloy steels were being used increasingly for both military and non-military applications. Nickel steel was used for parts of the first electrical generator at Niagara Falls. In 1898, the bicycle industry began using nickel steel for chains and later for tubing. Power shovels with manganese steel teeth were used to dig the Panama Canal in the years between 1904-1914. The Wright Brothers' plane, the Kitty Hawk, which made the first powered flight in 1903 contained nickel-chromium steel. By 1905, the automobile industry was beginning to write its own specifications for alloy steels. In short, the age of alloy steels was just beginning at the close of the nineteenth-century.

Shaping and Finishing Steel: Once steel has initially been produced, it is shaped and finishing in a number of ways. The most usual procedure is to work the ingot while still hot by rolling, that is, by the plastic deformation of the metal by passage through rollers. This is the most commonly used of all shaping operations, because it lends itself to high production with close control of the finished product.

Steel ingots can also be forged into the approximate shape of a finished object by hammering or pressing. Molten steel can also be cast into a mould; though this practice was not as common as the casting of pig iron. Steel rolls and bars are cut, ground and milled into required shapes. During the course of shaping and finishing, the steel being processed is dipped into pickling liquids (generally acids of some sort) to remove scale, and then neutralized with a basic solution such as lime water.

Most of the hot rolled steel is produced as the raw material for cold rolling. This improves the surface finish, confers higher mechanical properties, yields a more uniform structure, and rolls to closer dimensional tolerances. During the course of cold rolling, a water-soluable oil emulsion is sprayed on the rolls to keep them cool and to lubricate the strip as it passes. The process of cold rolling goes back to the eighteenth-century when John Westwood took out an English patent in 1783 for cold rolling iron to improve its surface finish. Round wire cods were being industrially cold rolled in Germany for the production of clock and watch springs as early as 1830.

Iron and steel were also surface treated with a number of different substances to prevent corrosion or to make them more suitable for certain uses.

Tin plating of steel sheets for making food containers goes back to the end of the nineteenth-century. A coating of tin about 1/40 the thickness of a human hair prevents oxidization of the outside of the can, keeps a bright finish, resists attacks of food acids within, is non-poisonous to the contents and easily soldiered.

In the first two decades of the nineteenth-century, two men who had been independently in the business of preserving food in glass jars went into the business of manufacturing tin cans, using imported Welsh tin plate. The first tin plate in America, manufactured specifically for use in food cans, was produced at the Hussey's Copper Works in Pittsburgh in 1858-59.

For the next fifteen years, there does not appear to have been any further attempts to produce tin plate in the United States. Local producers could not compete against the duty-free Welsh tinplate, either in quality or price, until 1890. In that year, William McKinley, then a Congressman from Ohio, wrote a tariff act which increased the duty on imported tin plate from 1.1 to 2.2 cents a pound. This give the American industry a chance to compete in their own markets. A number of sheet rolling mills installed tinning equipment and new tinning mills were built. Twenty tinning mills went into operation in 1891 and another ten were being built. In the next fifteen years, production increased from 1,118 tons in 1891 to more than 287,000 tons in 1897.

Iron was used as the base for the small American tin plate industry until 1875, at which time steel was introduced. In the early days, sheet for tin plating were rolled on hand sheet mills. The coating was applied by immersing the sheets in a tank of molten tin. This became known as the hot-dip method. This remained in use until the electrolytic process was introduced before World War II.

Steel was also coated with terne, an alloy of 15 percent tin with 85 percent lead. Terne coated steel could not be used for food containers, since it contained lead, however it was used in such non-food uses as paint containers and structural features for buildings.

Galvanizing, or the coating of iron and later steel with zinc dates back at least to the later half of the eighteenth-century. The industrial use of the process dates back to 1836 when an M. Sorel patented a process of coating in which the iron was pickled in acid and fluxed with ammonium chloride before dipping in molten zinc.

The practical success of galvanizing in protecting iron from corrosion in outdoor uses lead to the rapid growth of the industry from 1840 onwards.

One of its earliest uses was in the production of corrugated iron sheet for roofing. This practice rapidly spread around the world after its development by John Spensor of West Bromwich, England in 1844. The galvanizing of wires by dipping bundles of wires in molten zinc began with the introduction of the telegraph. A machine for continuously annealing and galvanizing wire was invented by George Bedson in 1860. The wire was passed as a continuous strand through the annealing furnace, through an acid pickle and then into a bath of molten zinc. After processing, it was wound onto a reel. Galvanizing was soon carried out extensively on steel wires used for a multitude of outdoor purposes, including ropeways, guy wires for suspension bridges, and wire fencing.

During the last part of the nineteenth-century, an extensive industry developed around the production of galvanized wire for fencing. Modern methods of stringing wire fencing were developed around 1880. These included the use of stranded wire, ratcheting and barbed wire.

In 1842, George Elkington established in Birmingham, England, the first plant for practical electroplating. This was also the first practical commercial application of electricity. There is no evidence that the process was used in the American iron and steel industry before the twentieth-century.

5.3.6 Residual Environmental Hazards from the Nineteenth-Century

5.3.6.1 Mining. In comparison to the amount of attention focused on the consequences of coal mining, there is relatively little literature on the environmental aftermath of iron ore mining. Since this is open pit mining, subsidence is not a problem, but erosion, waste piles, and contamination of groundwater and surface water are major issues.

The extent to which nineteenth-century mines are still being worked, or conversely, have been abandoned, or the land reclaimed, is a point on which we have little information. We suggest that regional retrospective assessments of iron mining may be needed. Appendix 1 provides information on location of mining activity which would aid such assessments.

5.3.6.2 Coking. Quenching water from coking ovens contained tars, phenols, cyanides, and nepthalene. It was poured on the ground or into streams, or was reused to quench molten slag from associated blast furnaces where its residues may still contribute to leachates. Other waste products from early coking processes include cyanide salts and ammonium salts. The byproduct coking ovens which came into use at the beginning of the twentieth-century produced ammonia liquors and lime sludge, and concentrated cyanides in the heavy fraction of coal tars left behind. "Moondust"--a highly toxic, flammable, and volatile residue of coal gas, is a serious problem in removing or cleaning old pipes or tanks that once held coking gases.

5.3.6.3 Blast Furnaces. The highly porous firebrick used in the construction of early blast furnaces absorbed ash, trace amounts of heavy metals, cyanide and other hazardous compounds. Given the present fashion for reuse of old industrial materials in homes or business facilities, brick from a dismantled blast furnace could be tempting in spite of, or because of, its scarred and burned condition and could potentially be put to use as decorative brick in restaurants, as edging in gardens or park land, or even in new residential construction.

Brick from abandoned blast furnaces could be analyzed to determine whether they contain absorbed chemicals but would need to be done at each dismantled or ruined furnace, since not only do iron ores and cokes differ in chemical composition, but the bricks themselves differ with local kilns. It may be safest to discourage scavanging of blast furnace brick altogether, either on an individual or a commercial basis, but this could be a problem with the 'iron boom' furnaces of the 1890's, since many of them are in areas that have reverted to rural terrain.

The wet scrubbing of blast furnace gases was developed in the second half of the nineteenth-century. These scrubbers produced large quantities of highly contaminated water, containing among other things cyanides, heavy metals including barium and chromium (both of which EPA considers hazardous), tars, and other contaminents. There are few, if any, existant records concerning the disposition of this water. Given the general nineteenth-century practice of disposing of industrial waste dumping them into a nearby body of water or into above ground dumps, it can be assumed that this was the fate of much of the scrubber water. If this material was dumped into rivers or lakes, some of the contaminents could still be present in sediments or trapped behind dams or embankments. Ground dumps could still be leaching some contaminants into the groundwater, depending on a number of factors such as soil conditions and the groundwater table.

The heavy particles from the stack gases, those settled out by the downcomer pipe and associated chamber, were carted off for dumping in solid form. Again, nineteenth-century sources are silent on the fate of this material, but it probably was generally dumped on the ground. There are man-made mountains in some of the old iron and steel areas that have been built up over years of dumping. The EPA does not currently list fly ash as a hazardous substance; however, it does contain both barium and chromium which are listed as hazardous substances. Unless a furnace was known to have been abandoned or closed in the nineteenth century, it would be virtually impossible to isolate that century's contribution to a continously growing mountain of ash.

Cyanides of the alkali metals were in the gases in all parts of the nineteenth century blast furnace. An 1882 study found that the average quantity of such cyanides in a coke fueled blast furnace for six consecutive days was 6.58 grains of cyanogen per cubic foot of gases in the hearth and 1.65 grains of cyanogen per cubic feet of gases at the top. This yielded 130 pounds of cyanogen at the hearth and 33 pounds of cyanogen at the furnace top for each ton of pig iron produced. It also indicated the presence of at least double these quantities of mixed sodium and potassium cyanides.[12]

It was realized at the time that a considerable quantity of cyanides escaped from the furnace in fumes and flue dusts. There were a number of recorded instances of cyanide dumping causing fish kills and other problems. In 1901, twenty tons of flue dust was disposed of in the River Ems in Styria, causing a massive fish kill. The furnace company was held liable and fined $14,000. In 1898, a similar incident had occurred on the Rockaway River at Wharton, New Jersey.

Tracing these cyanide compounds at the present time would reqire chemical detective work. Some of it apparently was disposed of in the rivers and is possibly still stored in river bottom sediments or behind dams and embankments. Land dumping could also create problems if this material is disturbed. If old solid masses of slag were crushed or broken up, the cyanide compounds trapped within the slag could also reemerge.

It is highly likely that asbestos was used in some parts of the blast furnaces, in the nineteenth-century. If old furnaces were dismantled, asbestos dust, a carcinogen, would be present, possibly in large quantities.

5.3.6.4 The Special Case of Alabama. One state that merits particular attention is Alabama. In the years following the Civil War until the end of the century, there were a large number of blast furnaces hastily constructed, near the iron and coal fields of Alabama. By the end of the century, most of these furnaces had been just as hastily abandoned when the prices of pig iron dropped below the operating costs of many of these furnaces. The demise of the furnace often brought the demise of the 'boom towns' that had been built up with the furnace.

In 1892, there were 55 blast furnaces in Alabama; at least 33 of them had been built in a boom period between 1885-1890. These included 6 furnaces located in and around the area of Birmingham and 25 furnaces located in the iron and steel 'boom towns', including 5 each in Bessemer and Sheffield, 4 in Ensley, 2 each in Anniston, Fort Payne and Florence, and one each in Decatur, Talladega, Piedmont, Gadsden and Attalla.[13] By 1940 there were only 17 fully operational furnaces.

A quotation from the founder of the Bessemer furnace shows the spirit behind the construction of these furnaces. Henry F. De Bardeleben, while pointing to a map of Alabama, was quoted as having said:

> Here is where we are going to establish a young city. . .we are going to build a city that will contain eight furnaces within two years, and we propose to extend two railroad lines touching Tuskaloosa and another outlet to be determined. . .We are going to build a city solid from the bottom up and establish it on a rock financial basis. No stockholder will be allowed to come in who can't make smoke. It will take $100,000 to come in, and the man who can make the most smoke can have the most stock.[14]

By the 1890's, the boom was on the wane. The hastily constructed Alabama furnaces could not meet the prices set by the northeastern furnaces. While some of them were dismantled, in many cases these boom town furnaces were simply abandoned. In the three year period between 1890 and 1893, furnaces closed down in Attalla, Gadsden, Anniston, Decatur, Sheffield, Florence, Fort Payne, Piedmont, Talladega, and Birmingham.[15] As one writer remarked, these furnaces are "marked today only by heaps of slag--many built upon a foundation of optimistic speculation rather than actual knowledge."[16]

These furnaces are likely to be marked not only by slag, but by any more harmful products that have not dissipated naturally. A number of factors make these furnaces good candidates for long term hazardous effects. First, they were hastily constructed originally, often by people who knew little about the iron industry. They did not hire the best ironmasters and had a record for safety that was low even by nineteenth-century standards. The hasty abandonment of these sites argued against any effort to dispose of wastes. Standard operating procedure was to strip anything perceived as valuable, padlock the site and leave. Finally, the abandonment of not only the furnace, but in some cases the boom town itself, or at least a large part of it, has left some of these sites deserted since the nineteenth-century. It is only now that the areas are being redeveloped, and latent problems could start to surface.

Alabama had the highest number of late nineteenth-century boom town furnaces, however, other areas also experienced 'iron booms,' though on a much smaller scale. These included areas around Kansas City, Missouri; Minneapolis, Minnesota; San Diego, California; Forth Worth and Dalls, Texas; and Chattanooga, Tennessee.[17]

These furnaces should be identified and the sites examined for the presence of residual hazardous substances. In Alabama, the furnaces themselves can be identified through a 1940 publication of the Woodward Iron Company, Alabama Blast Furnaces, which lists all known blast furnaces built in Alabama up to 1940, and their status as of that year. Once the furnaces have been located, on-site examination, possibly combined with historical sources such as newspapers from the towns involved, could be used to identify waste dumps and abandoned facilities, before any redevelopment occurs.

5.3.6.5 Cast or Wrought Iron: The greatest dangers from the production of both wrought and cast iron were to those people who worked directly in that production. However, there are some residual products that could still be present into the twentieth-century.

Iron was sometimes coated with oil to prevent rust. In most cases, this oil would be decayed by now, however, if it was thrown into the slag heap, it could be leaching out.

Nineteenth-century forges often produced a wide range of consumer goods such as railings, gates, balconies, bedsteads, lounges, cradles, chairs, cemetary enclosures, architectural features such as lintels, caps, posts, and fountains, firescreens, fences, and baskets. These items were generally painted, gilded or varnished.[18] The paints used were lead based and it is probable that residues from paint wastes are still present. If the waste paint were dumped into rivers, lead could be present in river sediments. If these wastes were dumped out on the ground, there could be leachates containing lead coming from the dumpsite.

After the half-blooms were hot rolled into bars, these bars were passed through several cleansing baths to remove scale and impurities. Once these cleansing baths became sufficiently contaminated, it can be assumed that they were also dumped--into running water, on the ground, or into the slag heap. Sediments from these chemical baths could be present after 75-100 years, depending on the dump site.

One of these cleansing processes was described by Scientific American in 1869. The iron bars were first dipped into a hot solution of sulphuric acid to remove scale. Then they were plunged into a hot bath of lime water to neutralize the acid. Finally, they were run through a bath of hot water and then rubbed with pumice before being sent through the next set of rollers.[19] Lime sludge associated with facilities used to neutralize the pickling liquor are on the EPA's list of hazardous wastes.

5.3.6.6 Steel-Making, Shaping, and Finishing. Most of the potential remaining hazards from the production of steel in the nineteenth-century would be in the form of sludges and dusts dumped either on the ground or in a convenient water supply. The sludges and dust produced during the production of ferromanganese iron are considered a toxic waste stream by EPA. These could still be present in slag heaps and other disposal areas, or in river sediment.

A large number of hazardous substances, including acids, lime water, heavy metals, cyanide compounds and waste oils were part of the various treatment of steel once it had been formed into ingots. Many of these substances could remain until the present day.

The acids used in pickling steel before rolling were probably dumped into the rivers, and would have probably dissipated by the present day. However, they could still be present if they were dumped into the slag heap or on the ground. Any wastes from the grinding of leaded or chromium steel would be hazardous. Steel was often heated in molten salts to prevent brittleness (annealing). In some cases, it was customary to use cyanide salts. Forged steel was quenched in both water and oil baths which contain cyanide. We have no way of knowing now where these waste baths were dumped.

Wastes resulting from the electroplating process contain both nickel and cyanide. If these wastes were dumped into rivers, both the nickel and the cyanide could show up in sediments downriver. Scum from galvanizing and terning is generally skimmed off and dumped on the ground. Terning scum would contain high concentrations of lead.

Many nineteenth-century iron and steel plants had a series of locomotive shops associated with them. The large steel industries often had their own fleet of trains that they kept repaired in their own yards. Waste oil from these locomotive yards could still be present, particularly if it were dumped in the slag heaps.

5.4 THE LAND OF THE DAMMED

5.4.1 Summary

Before 1900, 1582 dams were built in what is now the United States. About 20 percent of these dams are now hazardous. If they should fail, there could be substantial loss of life. There would almost certainly be significant environmental impacts. Behind these old dams--and the many twentieth-century dams also classified as hazardous--there is very likely sediment loaded with toxic wastes, some of which also date from the nineteenth-century. Whether dams fail, are deliberately breached to prevent unexpected failure, or are repaired (which usually requires dredging) these toxic sediments may re-emerge as an environmental, health, and safety problem. Very little research and analysis has been done to determine the extent and significance of this source of hazards.*

5.4.2 Location of Nineteenth-Century Dams

Three quarters of the 1582 nineteenth-century dams are located in ten states,(1) as follows:

Colorado	219 dams	Rhode Island	94 dams
Connecticut	215	Pennsylvania	87
Massachusetts	141	New Hampshire	82
Michigan	129	Maine	76
California	103	North Carolina	64

Fourteen states have between ten and fifty old dams:

Illinois	13 dams	Ohio	25 dams
Kentucky	11	South Carolina	12
Minnesota	42	Texas	16
Missouri	11	Utah	15
Maryland	10	Vermont	11
New Jersey	16	Virginia	35
New York	35	Wisconsin	32

Twenty two states have fewer than ten such dams:

Alabama	8	Iowa	4	Mississippi	4
Alaska	1	Kansas	4	North Dakota	2

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*NOTE: Because of the paucity of bibliographic and documentary information about this area of concern, most of the information has been gathered through informal discussions (by telephone and in person) with such authorities as we could locate. While these persons generously shared their knowledge and time to help us, such information is necessarily subject to some risk of misunderstanding and vagueness and should therefore be taken as tentative and non-definitive.

Arizona	7	Louisiana	1	Oklahoma	3
Arkansas	2	Montana	8	South Dakota	2
Delaware	5	Nebraska	6	Tennessee	1
Georgia	2	Nevada	2	Washington	6
Hawaii	3	New Mexico	5	West Virginia	3
				Wyoming	9

Only Forida, Idaho, Indiana, and Oregon have no dams identified as having been built before 1900.

Not all old dams are unsafe; in fact some of the older dams are in stronger condition than more recent ones because they tended to be extensively overdesigned and overbuilt.(2) They become hazardous when they are allowed to deteriorate and problems remain undetected or ignored.

The Corps of Engineers recently surveyed over 49,000 public and private dams in fifty states and four territories. The survey included all dams over 25 feet in height and with a maximum impounding capacity of 50 acre/feet or more. Dams were inspected for structural soundness. The Corps recorded:

- name of dam or impoundment
- river or stream on which it is located
- type of dam
- year completed
- purpose of dam
- height
- maximum storage capacity
- nearest city
- distance to city
- population of city
- downstream hazard potential

The Corps inspection found that 322 of the nineteenth-century dams were hazardous; this included 61 out of 141 in Massachusetts, 51 out of 82 in New Hampshire, and 78 out of 87 in Pennsylvania. See Table 5.4.1. The population which would be put at risk from failure of one or more of these dams can be estimated from Corps records. Action with regard to unsafe dams is to be determined by States. Failure of dams would cause, in most cases, significant environmental impacts. Repair or restructuring of dams will also have potential environmental impacts. Any dredging which must be done (as well as sudden or deliberate breaching of the dams) will release sediments which may well contain toxic wastes.

The sediment and its contents may also be a problem with nineteenth-century dams which are structurally sound and may be retrofitted for hydropower, an action which is now encouraged and to some extent assisted financially by the U.S. government. There are of course also other reasons for periodic dredging of reservoirs, which always fill up over time. Any dam - nineteenth-century or twentieth-century - may contain toxic wastes in its sediments, from urban run off, industrial effluents, erosion of agricultural lands treated with pesticides and fertilizers, etc. The older dams have been collecting such sediments over a longer period, and are also more likely to have trapped toxic wastes from the 1800's, when mining and manufacturing operations routinely disposed of toxic materials by dumping them into streams or on the ground. Of special concern would be the

TABLE 5.4.1

HAZARDS OF NINETEENTH-CENTURY DAMS

	Total Number 19th Century Dams	Hazardous Rating* 1	2	3	Not Rated
COLORADO	219	-	4	3	212
CONNECTICUT	215	-	1	-	214
MASSACHUSETTS	141	68	41	31	1
MICHIGAN	129	-	1	1	127
CALIFORNIA	103	1	-	6	96
RHODE ISLAND	94	8	24	62	-
PENNSYLVANIA	87	78	2	7	-
NEW HAMPSHIRE	82	51	26	5	-
MAINE	76	3	30	43	-
NORTH CAROLINA	64	7	11	46	-
MINNESOTA	42	6	9	4	23
VIRGINIA	35	7	4	23	1
NEW YORK	35	17	12	5	1
WISCONSIN	32	7	10	7	8
NEW JERSEY	16	13	2	1	-
TEXAS	16	9	-	7	-
UTAH	15	13	1	1	-
ILLINOIS	13	-	-	3	10
SOUTH CAROLINA	12	4	3	5	-
VERMONT	11	1	1	-	9
MISSOURI	11	-	-	-	11
KENTUCKY	11	8	2	1	-
MARYLAND	10	5	3	2	-
WYOMING	9	-	1	8	-
MONTANA	8	-	3	5	-
ALABAMA	8	-	1	7	-
ARIZONA	7	3	-	4	-

TABLE 5.4.1 (cont'd)

	Total Number 19th Century Dams	Hazardous Rating* 1	2	3	Not Rated
NEBRASKA	6	3	2	1	-
WASHINGTON	6	1	-	5	-
DELAWARE	5	2	-	3	-
NEW MEXICO	5	1	1	3	-
IOWA	4	-	-	4	-
KANSAS	3	-	-	3	-
MISSISSIPPI	4	-	-	4	-
HAWAII	3	-	-	3	-
OKLAHOMA	3	-	-	2	1
WEST VIRGINIA	3	-	2	1	-
ARKANSAS	2	2	-	-	-
GEORGIA	2	-	-	2	-
NEVADA	2	1	-	1	-
NORTH DAKOTA	2	1	1	-	-
SOUTH DAKOTA	2	-	-	2	-
ALASKA	1	-	-	-	1
LOUISIANA	1	-	-	1	-
TENNESSEE	1	-	-	-	1
OREGON	0				
D.C.	0				
FLORIDA	0				
IDAHO	0				
INDIANA	0				
Total	1582	322	213	331	716

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*1 = most hazardous,
3 = not hazardous

materials identified in earlier case studies: lead, mercury, arsenic, and cyanides, which were used in or byproducts of many different industries.

The Corps of Engineers dam inspection program rated the hazard potential of dams solely on structual soundness. No testing was done to determine the content of sediments.

5.4.3 Sediment Sampling

Today water quality is routinely monitored. But little is known as to the location of massive amounts of industrial and other waste dumped into water before the passage of water quality laws. A number of agencies do sediment sampling, including the Corps of Engineers, the Geological Survey, the Mine Health and Safety Administration, and the Soil Conservation Service. However these sampling programs generally collect two types of data: sediment density and size distribution. They are interested in the amount of sediment present and in how fast a reservoir can be expected to fill.(3)

There appears to have been no systematic, qualitative analysis of sediments; where this analysis has been done at all it has been on a local and sporadic basis, mostly by a few university professors and students. For example, a graduate student at the University of Minnesota is investigating lake sediment for lead content. He reports a strong correlation between the amount of lead in lake sediment and the increasing use of automobiles, in the region he is studying.(4)

There is one possible source of data, already collected, which could shed light on the dam sedimentation - toxic waste issue. The Department of Energy, as part of the National Uranium Resource Evaluation program, commissioned core sampling of sediments on a three-mile grid throughout the United States.(5) This program has almost been completed in some regions; however the Los Alamos National Laboratory for example carried out sampling throughout the Rocky Mountain area and other laboratories completed at least a major portion of the sampling in other areas. The sampled sediments probably include many from old dam reservoirs. The core samples would provide data on sediment contents. The samples were subjected to neutron activation and the automated analysis produced recorded data which would identify, classify, and list not only uranium (which was the object of the search) but many heavy metals and other toxic materials. The testing procedure - which was developed with public resources, and is said to be much faster and less expensive than chemical analysis - and the data, now in the public domain, could possibly be utilized to develop a profile of hazardous sediment concentration.

5.4.4 Areas of Special Concern

In the nineteenth-century, two major sectors which would have produced byproducts or wastes which could have remained in reservoir sediments until the present time, are mining and metal processing. In the case of mining, little has been done to analyze the sediments behind even those dams especially built to contain mine tailings. The Mine Safety and Health Administration (MSHA) of the Department of Interior has supervisory responsibility for these dams but is primarily concerned with potential for dam failure or overtopping and mud rushes. Little or no attention has been paid to the contents of tailing dam impoundments and the possible hazards if these contents are released into the environment.(6)

Mining was the primary industrial activity, for example, along the Colorado River. Most of the dams in this area were built to divert water for mining processes, especially gold and silver mining. Although the dam was generally upstream of any dumping, sediments would build up behind dams further downstream.(7) The Bureau of Mines Annual Report can be used to locate some of these old mining areas. It provides data on the tonnage mined in each state by year, identifies mining areas, and in many cases specific mine facility locations.

Mine tailings can contain such potentially hazardous components as cyanides, lead, cadmium, and heavy metals. The tailings were often continously dumped into streams or on their banks for many years. In some areas, scouring floods could have carried off much of the waste after mining was discontinued; in other cases considerable quantities may have built up in sediments.

Pennsylvania was the site of extensive coal and iron mining in the nineteenth-century, and also has 87 dams dating from that period. Many of these dams are near population centers. Structural failure of a dam could be compounded by the release of dangerous chemicals lying latent in the sediments. These sediments may also be disturbed or moved during attempts to repair, rehabilitate, or retrofit the dams. It is occasionally necessary to intentionally breach a dam with little forewarning in order to prevent downstream flooding in a populated area.(8) In all of these cases, it would be useful to know the content of sediments when decisions must be made.

Another major sector of concern is metal processing and its possible contribution of toxic wastes in sediments. These wastes might include lead, cadmium, mercury, arsenic, cyanide, cobalt, and antimony. Early processes for lead extraction for example were less efficient and produced larger quantities of heavy metals in wastes than modern procedures. The chloralkali industries used mercury which found its way into streams. Smelters released cadmium, arsenic, and heavy metals. Blast furnaces, foundries, rolling mills, and metal plating operations released large quantities of such materials as cyanides, ferromanganese sludges, acids, and tars.

Besides those wastes which were directly dumped into streams or on land which then eroded into streams, chemicals which were released into the atmosphere may also have settled and been washed into rivers and lakes. This is known, for example, to occur with lead from automobile emissions and may also occur with cyanide and arsenic.

5.4.5 Future Assessment Needs

Sediment contamination is clearly an example of potential future problems left behind by old industrial processes (as well as by more modern ones). The problem is moreover likely to re-emerge or become very important as another nineteenth-century technology, old dams, nears obsolescence. This is an area of concern which has received little attention and where little data exists. Further assessment is obviously merited.

Investigation of the hazards which are left from the nineteenth-century would of course also reveal the extent of more recent contamination in the same locations. Limiting the present discussion to nineteenth-century residuals, however, the assessment task might have several phases:

- Phase I: Using the data represented in Appendix II, compare the location of nineteenth-century dams with known concentrations of nineteenth-century industries from which wastes containing toxic materials would constitute potential hazards. From local historical materials, such as pictures and descriptive accounts, attempt to identify waste disposal methods and locations of effluent outlets, dumps, etc., and streams which would be likely to receive toxic wastes. Match locations of sources with existing old reservoirs. Emphasize reservoirs which may be breached as a result of unsafe dams or in the process of repairing dams or rehabilitating them for new uses such as hydropower generation.

- Phase II: Collect and evaluate the few studies which have been done of sediments in the U.S. and other countries, for clues as to possible sedimentation patterns, the likelihood of detrimental consequences from accidental release or from dredging of sediments, and methodologies and techniques to be used in detailed assessment.

  Optional: attempt to secure and re-analyze data from the Department of Energy's National Uranium Resource Evaluation for identification of sediment contents.

- Phase III: Design and carry out a sampling program on sites selected on the basis of Phase I results.

5.1 FOOTNOTES

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[5] Imperial Mineral Resources Bureau, The Mineral Industry of the British Empire and Foreign Countries, Arsenic, 1913-1919 (London: His Majesty's Stationery Office, 1920), p. 9.

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[7] U.S. Congress, Senate, Arsenic Deposits in the United States, S. Doc. 27, 68th Cong., 1st Sess. (Jan. 24, 1924), p. 3.

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[25] Whorton, p. 21.

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[62] Ibid.

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6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

Twenty technologies, systems, or industrial materials were identified as having a significant potential for causing delayed environmental and health problems. See Table i. Other "public" or urban technologies such as sewers, bridges, and rail lines, whose deterioration over time may constitute threats to health and safety, were noted but not further assessed since those problems are generally better known.

TABLE 6-1

Technologies for Retrospective Assessment

High Priorities	Medium Priority	Low Priority
Arsenic compounds	Asbestos	Lyes
Coal industry	Cadmium	Radium
Iron and steel industry	Sulfuric acid	Bleach industry
Dams and reservoirs	Explosives industry	Fertilizer industry
Lead compounds	Hat making industry	Wells
Mercury compounds	Underground urban networks	
Electroplating industry		
Tanning industry		
Canals		
Cyanide compounds		

Exploratory assessment of nineteenth century technologies indicates that toxic materials, the associated toxic wastes, and deteriorating structures are the major concerns. A number of toxic materials - especially arsenic, lead, mercury, cyanide, and asbestos - were widely used in a large number of industries, or were common by-products of mining and manufacturing. Aging, abandoned, or neglected mines and dams entail problems because of structural deterioration. Reservoirs, canals, and wells store unidentified materials which may be gradually leaking into the environment, or may be suddenly and inadvertantly released in a variety of ways.

Old toxic substances may now be found:

- on land surfaces, in slag heaps, waste dumps, and refuse piles;
- subsurface, as a result of repeated pesticide applications, or as a result of unmarked waste burial, slow percolation of leachates, leakage from pipes, or use of contaminated soil as fill;
- in gullies ravines, and abandoned canals and wells, where industrial and mining wastes were frequently dumped;
- concentrated in sediments at the bottom of reservoirs, streams, and lakes;
- in old buildings as dusts, caked deposits, and trash piles, or as a component of paint, wallpaper, and other structural or decorating elements;
- as pigments or finishes on products and artifacts which are still used, collected, restored, and displayed as cherished antiques.

These hazardous legacies of the past may re-emerge as a result of current activities and programs. As population grows and residential development spreads, land once used for mining or manufacturing is reclaimed for other uses. Dredging of sediments is routinely done to free reservoirs and navigation channels of silt. It is presently increasing because of retrofit of old dams to generate hydroelectricity, development of new coal export ports, and to increase the depth of drought-depleted rivers used for shipping. Sediments may also be disturbed and released because of dam failure or deliberate breaching to remove or repair dams.

Old buildings, particularly abandoned manufacturing facilities, are increasingly reclaimed as shopping malls, restaurants, offices, studios, and residences. Victorian furniture is now considered "antique" rather than old or second-hand, and is increasingly sought after and lovingly restored. More utilitarian recycling and materials recovery is also increasing. Old mines may be re-opened. All of these activities tend to bring forgotten hazards to the surface or increase human exposure to them.

Nineteenth century toxic substances may be dwarfed in volume by those imposed on the environment since the "chemical revolution" in industry in the 1940's and '50's, but nevertheless they can present a significant risk in some localities and to special segments of the population. Many nineteenth century industries were small and widely dispersed. The catalog of known chemicals and useful raw materials was much smaller than today, and thus some persistent toxic substances were associated with a wide variety of industries and activities. Those which were used in consumer products, as building components, and as agricultural pesticides are likely to be of nation-wide concern.

Populations especially likely to be exposed to nineteenth century toxic substances include workers involved in land excavation, dismantling or restoring old buildings and manufacturing facilities, and agricultural workers. Also at risk are professionals or amateur who repair, restore, and refinish antique furniture, art objects and curios, or those who collect, handle, and use such objects. Occupants of reclaimed buildings and sites may also be at risk. Little is known about the extent or significance of this class of hazards, and the evidence of public health problems is largely anecdotal. This however may be only because little or no systematic attention has been given to the subject.

Four case histories were developed during this project and are summarized in the report: arsenic compounds, the coal industry, the iron and steel industry, and dams and reservoirs.

Arsenic compounds were widely used in paints, pesticides, and a variety of consumer products as well as in industrial processes. The effects of many years of use of arsenic compounds as pesticides is highly controversial. In some areas of New England there have been repeated reports of arsenic poisoning from well water or soil contamination. The source may very well be unidentified residues from a number of nineteenth century industries in that area.

In spite of decades of concern, continuing research is needed on environmental problems associated with abandoned underground coal mines. The Office of Surface Mining, which now also has responsibility for abandoned coal mines, is not empowered to carry out such research. It is possible that sulfur compounds from coal mining, coal wastes, or coal combustion, as well as from other industries in the past, may be contributing to the acidity of some lakes, acidity which has been assumed to be "natural" because it cannot be traced to more recent coal-burning or automobile emissions.

Much of the pollution from iron and steel production was deposited on site. Toxic substances contained in quenching water and slag heaps are likely to be a continuing source of contamination as they continue to leach. "Moondust," a highly toxic and volatile residue of coking gas, has recently been revealed to be a hazard in removing old pipes, but almost nothing has appeared in the technical literature on this subject.

Many of the toxic residues from the past century are likely to be concentrated in sediments in lakes and reservoirs as a result of waste disposal in streams, or leaching and erosion from slag heaps and otherwise contaminated sites. Over long periods of time, these materials would have found their way through watersheds and streams into sediments behind old dams. There is surprisingly little data on the chemical content of sediments. These old sediments may be mobilized by dredging, by storms, by dam failure, or by the deliberate breaching of dams for purposes of removal or repair, with potentially severe impacts on downstream ecological systems and on human health and safety.

"Public technologies" - large scale public works and urban networks such as water carriage and utility lines - are also a potential source of present and future environmental problems. Many of these technological systems were put in place in cities across America within a relatively short span of time: 20 to 50 years. Like all man-made systems, they must have a finite lifetime. Assuming, therefore, that they would tend to "wear out" at approximately the same time, this deterioration could theoretically cause an epidemic of environmental problems. In fact, this situation exists with regard to the physical infrastructure of our older cities. It is ameliorated to some extent by the fact that there have been peicemeal mitigation measures - i.e., replacement of wood, iron, or lead sewer pipes by sections, as they begin leaking. Another example is the nation-wide problem of bridge deterioration.

This retrospective mini-assessment gives little attention to public sector technologies because there is generally a clearly assigned responsibility for their monitoring (local government agencies) and many of the problems associated with aging public technologies have been at least identified and often some corrective programs are underway. The environmental implications for the future have not however been exhaustively assessed on a national basis.

6.2 METHODOLOGICAL OBSERVATIONS

Retrospective forecasting, perhaps better called retrospective impact assessment, can be a useful and indeed very much needed approach to strategic planning of environmental research and action programs. It provides a systematic procedure for searching out, at the conceptual level, possible unrecognized and unanticipated sources of risk and environmental deterioration. This exploratory mini-assessment indicated several steps which are needed within retrospective assessments.

The first is technical characterization of mining, manufacturing, processing, and other technology categories. Standard historical research procedures turned up a large volume of secondary descriptive material written during the nineteenth century about industry and technology. The history of science and technology is also a well developed field of study today. Neither of these bodies of literature, however, contains much information directly pertinent to environmental impacts of the technologies, other than what can be inferred from incidental information about waste streams. Neither contemporary observers nor (until very recently) later historians show much interest in such subjects as waste disposal techniques and sites. It is possible however that industry archives, or community archives such as those held by local historical societies may contain site-specific information.

The secondary literature provides guidance to sources of primary data which could not be explored within this project. U.S. Census reports, particularly the Census of Manufacturers, are another starting point. In general, governmental sources are of little help because there was relatively little industry regulation and required reporting. The Smithsonian Institution's Museum of American History and other specialized museums are promising sources. In recent decades the development of industrial archaeology has been adding to the store of information about our industrial past.

The second step is research and assessment aimed at mapping the most likely concentrations of residual hazards and further specifying and evaluating the significance of their potential effects. Given well developed packages of warning, information, and guidelines, local governments and groups at special risk could conduct their own retrospective investigations to pinpoint sources of risk to their members. To be directly useful, retrospective environmental assessment must eventually rely on thorough field work at the community and site level.

We have made some inferences from state of the art knowledge about materials now classified as toxic and about the likelihood of their persistence in the environment. In fact, however, there are large gaps in information about the behavior of these materials over long periods of time, about their migratory paths when released into the environment, and about the consequences of chronic low level exposure. Interviews with experts on toxicity and environmental health indicated that few of them had even though about non-contemporary sources, just as historians of technology had seldom though in terms of environmental effects. The information which is needed may be latent, and may become available once scientists are encouraged to think about these questions.

At the local level, much more information may be available from local records, archived in museums, historical societies, libraries, local government offices, and in some cases in a surviving industry. If the earlier phases of assessment suggest a high probability of residual hazards in specific locations sampling may be necessary both to determine whether remedial programs are necessary for a specific area, and to further evaluate the probability of, and significance of, potential problems in other localities with a similar history. In some cases it may be possible to re-examine samples already taken for other purposes. This report suggests the possibility that core samples taken during the National Uranium Resource Evaluation may have produced evidence about heavy metals in sediments, for example.

6.3 RECOMMENDATIONS

1. EPA/ORD/OSASS should continue to fund exploratory retrospective environmental impact assessment. High priority areas of concern for more detailed assessment include:

Materials	Industries	Systems
arsenic	coal	dams and reservoirs
asbestos	electroplating	canals
cyanides	iron and steel	urban networks
lead	tanning	
mercury		

These assessments should be planned so that, should they indicate problems of substantial magnitude and significance, they would lead directly to successive levels of assessment and action programs including regional and site-specific assessments, field sampling, and design of remedial measures.

2. EPA should consider the development of information bulletins directed at local communities to alert them to the possibility of residual risks from nineteenth century industry, and to suggest that local governments review their industrial history for possible sources of environmental contaminants and structural hazards. Information bulletins should also be targeted at occupational and avocational groups who may be particularly likely to be exposed to such risks.

3. EPA should initiate discussions with other responsible agencies on several areas of overlapping concern, such as:

   - toxic residuals from the nineteenth century which may be concentrated in sediments behind old dams (Army Corps of Engineers, Bureau of Land Management/DOI, State programs for dams found to be hazardous)

   - possible health and safety effects of toxic substances to which construction workers, furniture restorers, museum workers, and other occupational groups may be especially exposed (OSHA)

   - lead, arsenic, and mercury content of nineteenth century antiques and artifacts (Consumer Product Safety Commission).

APPENDICES

APPENDIX I

LOCATION OF NINETEENTH-CENTURY IRON MINING

In the northern states, the main ores used were the hematites from the rich deposits of the Lake Superior districts. These ores were primarily red hematites, sometimes hydrous, averaging 54% metallic iron with little gangue. They required no preparation before being burdened into the blast furnaces. They competed with the poorer local ores in all of the northern furnace districts. Some localities did continue to use the closer supplies of brown hematite. New York and New Jersey mined considerable quantities of magnetites for local use. These ores were sometimes used directly as they came from the mine and sometimes subjected to preparatory operations before they were burdened into the furnaces.

In the southern states, particularly Alabama, the ore supply consisted of both hematite and limonite. The hematites were a leaner ore, associated with 12-20% limestone, which rendered them essentially self-fluxing. The limonites were richer, though they required washing before use.

In 1907, 46,060,486 tons of hematite were mined in the U.S. This amounted to 89% of the total ore production. Production was divided as follows:

- 56 % from Minnesota
- 23% from Michigan
- 21% from Alabama, Wisconsin and Tennessee

Over 90% of the hematite produced (41,604,454 tons) came from what is commonly known as the "Lake Superior District" which lies to the southwest and north of Lake Superior. It includes the northern portions of Michigan, Wisconsin and Minnesota and parts of Canada. The district contained five distinct groups of mines or ranges. The Mesabi range, which began intensive development only in the last decade of the nineteenth-century, has become by far the largest producer by the first decade of the twentieth-century.

The Marquette Range was the first to be developed in the Lake District. It was discovered in the 1840's and became an important producer of iron ore in 1854. It is situated in the upper peninsula of Michigan, with its eastern extremity on the lake shore at Marquette, from which ore was shipped. The range extends westward for a distance of about 30 miles. Mining was most intensively developed in the vicinity of the towns of Negaunee, Ishpeming and Champion, with additional considerable production at Republic (a few miles south of Champion).

The Marquette Range produced both hard and soft ores. Hard ores were primarily massive or specular hematites, mined by drilling and blasting to form lump ores. Soft ores were somewhat hydrated, resembling limonite. The area produced both Bessemer and non-Bessemer ores.

The Menominee Range is located in the vicinity of the Menominee River, in both Michigan and Wisconsin. It was opened in 1877. The range was most active at Iron Mountain Michigan, about 40 miles south of the Marquette group, and about 40 miles from its shipping ports of Escanaba and Marquette. The predominant ore from the Menominee Range was soft blue hematite.

The Gogebic Range is also located on the boundary between Upper Michigan and Wisconsin, about 10 miles from Lake Superior and about 100 miles from Marquette. The area is about 20 miles long. It was most actively mined at Bessemer and Ironwood in Michigan and at Hurley, Wisconsin. Gogebic ores are soft blue, brown and black hematites, often high in Manganese. Almost all the ore from this region was Bessemer ore. The Range was opened in 1885.

The Vermillion Range is somewhat distant from the first three ranges. It is located in northeastern Minnesota, about 75 miles due north from Duluth. This range was also discovered in 1885. There were two main points of development in the Vermillion Range, Soudan near Tower and Ely, about 20 miles northeast of Tower. The ore from Soudan is hard, dense and somewhat specular hematite. It is exceedingly difficult to drill. Soudan ores contained both Bessemer and non-Bessemer ores. The Ely ores were all soft and of good Bessemer quality.

Mesaba Range was only mined significantly beginning in 1893. It is located about 20 miles southwest of Tower, and about 60 miles from Duluth. The range is about 40 miles long, and had important mining centers at Biwabik, Virginia, Mountain Iron and Hibbing. The ores produced from this area were red, brown and yellow, of soft loamy texture. Because of the fine, crumbly texture of these ores, there were easily carried out of the furnace during the blast process by the gases. They also tended to leave a deposition of carbon which obstructed the passage of gases in the furnace. Some of the Mesaba ores are of Bessemer quality.

A look at the comparative production of these five ranges from the years 1906 through 1908 will give some idea of the quantities of ore being mined and shipped from the area.

RANGE	1906 (Long Tons)	1907 (Long Tons)	1908 (Long Tons)
Mesaba	23,819,029	27,495,708	17,257,350
Menominee	5,109.088	4,964,728	2,679,156
Marquette	4,057,187	4,388,073	2,414,632
Gogebic	3,643,514	3,637,102	2,699,856
Vermillion	1,792,355	1,685,267	841,544
Totals	38,421,173	42,170,878	25,892,538

The so-called Clinton ores, or fossil ores were important in nineteenth-century ironmaking. They took their name from Clinton, New York, were they had once possessed considerable economic significance. There ores contain many fossil remains of the Upper Silurian Aga (hence the term fossil ores). These ores occur interstratified with shales and limestone, over a wide area of the country. Clinton ores reached their greatest economic development in the nineteenth-century in the Birmingham district of Alabama, where geologic folds and faulting has brought the ore beds into close proximity to the region's coal and limestone, thus assuring that all the basic raw materials for iron production were easily accessable. The Clinton ores also had economic importance in East Tennessee, Northwest Georgia, Southwest Virginia, Maryland, Central Pennsylvania and New York. They were also found in Kentucky, Ohio and Wisconsin. The structure of the ore itself varies with different sources, sometimes appearing as a replacement of fossils, again as oolitic concretions or ferruginous limestone. The ores vary in richness and are too high in phosphorus to be considered Bessemer ores.

Brown hematite was also mined in the U.S. for iron production. In 1907, 2,957,477 tons were mind, mostly from the Siluro-Cambrian deposits of Alabama, Virginia and Georgia. Deposits occur throughout the length of the Appalachians, and extend from Vermont to Alabama. Mining and smelting of brown hematite had considerable economic importance in eastern New York, Pennsylvania, central Maryland, southwestern Virginia, eastern Tennesse, northwestern Georgia and central Alabama.

Limonite was mined primarily in Colorado. The mines in Saguache County supplied part of the ore used in the Pueblo works.

Bog ore is a form of limonite that forms in pools of stagnant water. Deposits of bog ore had been identified in North Carolina, Canada, and the West, but they were not extensively used in the nineteenth-century.

Magnetite ores were mined primarily in the Eastern Coastal states, especially eastern New York, Northern New York, and Pennsylvania. The ores are generally dense and hard, showing a granular, semi-crystalline condition favorable to concentration by magnetization. They are generally non-Bessemer. The Western counties of Virginia and North Carolina had magnetite beds of Bessemer quality.

In Colorado a number of magnetite deposits were known, but mining took place chiefly in Chaffe County. These ores furnished part of the ores smelted at Pueblo. Utah, California and the Lake Superior District also had magnetite deposits that were mined to a limited extent.

Only a small amount of Siderite, or spathic ore, was produced in the United States in this period. Only 23,589 tons were produced in 1907. This ore was considered the least desirable for use in blast furnaces because of its high carbon dioxide content. It often occurred in association with other carbonates, especially calcic and magnesic, making the ore at least partially self-fluxing. When spathic ores were found in conjunction with bituminous matter, such as coal seams, it was known as "black band," when it was embedded in shales and associated with large amounts of clay, it was known as "clay ironstone." Black band was at some point considered of significant importance in Pennsylvania, West Virginia, Colorado, New York, and Connecticut.

APPENDIX II

INTERVIEWS

I. General: Candidates and Environmental Aspects

* Association of American Railroads, Washington, D.C.

Joseph F. Coates, President
J.F. Coates, Inc., Washington, D.C.

Eric Deloney, Editor, Historic American Engineering Record, Washington, D.C.

* Farmers Home Administration, U.S. Dept. of Agriculture, Washington, D.C.

Dr. Brook Hindle, Museum of American History, Smithsonian Institution, Washington, D.C.

Prof. Clay McShane, Northeastern University, Boston, Mass.

Dr. Robert Multhauf, Museum of American History, Smithsonian Institution, Washington, D.C.

Dr. Philip Ritterbush, Institute for Cultural Change, Washington, D.C.

Prof. Joel Tarr, Social Sciences Dept., Carnegie-Mellon University, Pittsburgh, Penna.

Dr. Robert Vogel, Supervisor, Dept. of History of Technology, Museum of American History, Smithsonian Institution, Washington, D.C.

II. Additional Case Studies Sources

Arsenic

Tom Holder, Soil Scientist, Soil Conservation Service, U.S. Dept. of Agriculture

David Rausch, Science and Education Administration, U.S. Dept of Agriculture

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[*] Spokesman preferred not to be identified.

Joe Kubota, Soil and Nutrition Laboratory, Cornell University Agricultural School, Ithaca, N.Y.

E.A. Woolson, U.S. Dept. of Agriculture, Beltsville, Md.

Coal Industry

James Culbertson, U.S. Geological Survey, Reston, Va.

David Maneval, Office of Surface Mining, U.S. Dept. of Interior

Charles Meyers, Office of Surface Mining, U.S. Dept. of Interior

M. Maxvick, Mine Safety and Health Administration, U.S. Dept. of Interior

Iron and Steel Industry

Dr. John Hoffman, Curator of Extractive Industries, Museum of American History, Smithsonian Institution

John Holeman, Soil Conservation Service, U.S. Dept. of Agriculture

Dams and Sediments

Paul Aamodt, Geotechnical Applications Group, Los Alamos National Laboratory

Harry Avery, Water and Power Resources Service, U.S. Dept. of Interior

Jane Cotton, Waterways Experiment Station, Corps of Engineers, Vicksburg Mississippi

* Development Resources Inc., Washington, D.C.

Harry Hardin, office of Inspection, Non-Federal Dams, Corps of Engineers

John Hopkins, Virginia State Water Control Board

Dr. Fred Lee, Engineering Research Center, Colorado State University

William H. Longenecker, National Agricultural Library, U.S. Dept. of Agriculture, Beltsville, Md.

Roger McHenry, Soil Conservation Service, Durant, Oklahoma

Michael O'Connell, U.S. Environmental Protection Agency, Las Vegas, N. Mex.

Dr. William Patrick, Louisiana State University

Prof. Larry Paulson, University of Nevada

Roger Saucier, Waterways Experiment Station, Corps of Engineers, Vicksburg, Miss.

Dr. Joseph Shapiro, Limnological Research Center, University of Minnesota

Robert Strand, Sedimentation Section, Water and Power Resources Service, U.S. Dept. of Interior

III. Internal Consultants, Dames & Moore

Michael Domenica, Senior Engineer

Steven Lamont, Chemical Engineer

William Levitan, Toxicologist

David Maloney, Physicist

Mark McBride, Hydrologist

Irving Remsen, Senior Engineer

Richard Tucker, Water Resources Engineer

Frank Vernese, Soils/Foundations Engineer

APPENDIX III

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Bauerman, Hilary. *A Treatise on the Metallurgy of Iron*. Containing outlines of the history of iron manufacture. . .processes of manufacture or iron and steel. . .etc. 5th ed., rev. and enl. London: C. Lockwood & Co., 1882.

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